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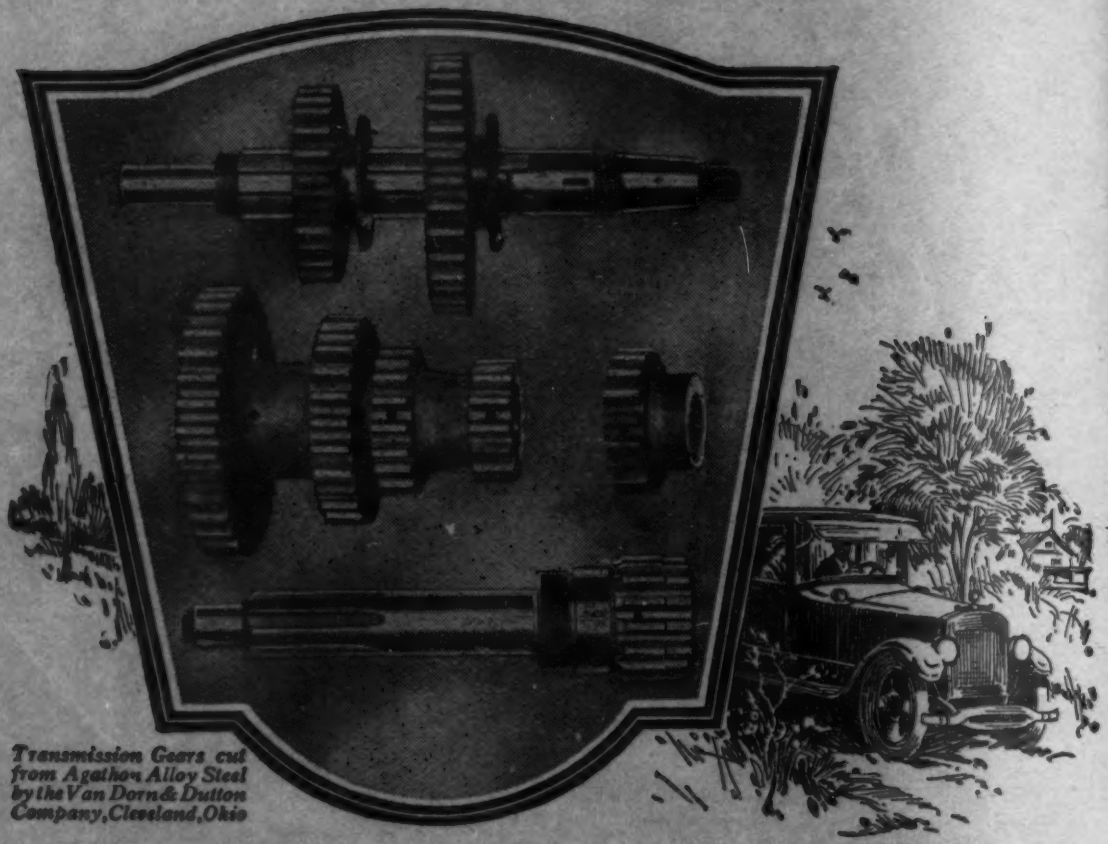

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TRANSACTIONS
of the
American Society for Steel Treating

Vol. IV Cleveland, November, 1923 No. 5

THE STEEL TREATERS' MOVEMENT

An editorial from *Iron Age*, Oct. 18, 1923.

THE demand for an organization such as the American Society for Steel Treating was strongly demonstrated during the week of Oct. 8 to 12 in Pittsburgh. At its fifth annual gathering this society successfully put through a technical program and a steel exhibition which would reflect credit on a much older body. In the quality of the papers presented, in the scope of the products exhibited, and in the attendance, the meeting was a surprise to some of the most ardent steel treaters.

A feature of the convention from a technical standpoint was the high standard set by the program as a whole. In a single session the names of some of the most prominent metallurgists of the country on the list of participants made it an occasion that recalled meetings only a few years ago of the steel section of the mining engineers. A second feature was the general youthfulness of the membership, testifying to enthusiasm in their work and to the impelling power behind the accomplishment of the future. Here, in a comparatively new field, or one in which scientific knowledge, methods and apparatus are transforming a crude art, are possibilities from which much will be heard in the near future.

The exhibition, commercially and in every other way, was a success and now ranks close to the older one which is a feature of the annual gathering of American foundrymen. There were some suggestions that there is danger of giving too much prominence to the commercial side. It is hoped that the commercial features will not be overstressed or to the

point of detracting from the technical possibilities of so promising an organization. Besides the usual showing of heat treating equipment of all kinds were the attractive exhibits of large and small steel companies and machine tool interests.

The new society is thus affording a meeting place, not only for the steel treater and metallurgist, but for all steel makers and users who would have American steel products benefit to the fullest extent from the scientific advance that is now so prominently before the industry.

STEEL TREATING FIELD EXPANDS

An editorial from *Iron Trade Review*, Oct. 18, 1923.

AMERICA'S youngest of the larger technical organizations, the American Society for Steel Treating, continues to attract attention by its vigorous growth. At Pittsburgh from Oct. 8 to 12, the society held the largest convention and exposition it has yet attempted and the unqualified success was a tribute to the sound and mature judgment of the management. Within three years, or since formation of the society in 1920, its membership has grown 50 per cent, or to approximately 3000 members. The membership is open to "the man at the fire" as well as to the metallurgist and the plant executive and the society is proud of the fact that it has been able not only to retain its membership but has been able to show gains in all classifications.

As is widely recognized the art of heat treatment has made its most rapid advance since the war, thus it is only natural that the American Society for Steel Treating in its growth and activities should reflect the increasing interest in that field. Registration figures at Pittsburgh showed the degree to which the organization is doing that. Total registration reached nearly 1800 of which 1492 were listed as members. With a net membership of 3000, the attendance of this year's convention was nearly 50 per cent and about 10 per cent better than at Detroit last year. Technical sessions at which

heat treatment problems were discussed were unusually well attended. The exposition covered one-third more space than in 1922 and yet was not sufficient to provide for all applications. During the five days the doors were open it is estimated over 40,000 people passed through, thereby establishing a new record.

Already the society is feeling need for expanding its field and is developing a new constitution defining its scope. As organized at present the purpose of the society is "to promote the arts and sciences connected with the treatment of iron and steel" and refers more specifically to the treatment subsequent to the manufacture of the material. In the utilization of alloy steels, the manufacture is becoming an important consideration. In addition, certain nonferrous metals are demanding attention as regards heat treatment. Therefore, appreciating the importance of the rapidly widening field the purpose of the society in the proposed constitution has been made to read "to promote the arts and sciences connected with either the manufacture or treatment of metals, or both."

The proposed broadening of the field of the society is logical, even though the "manufacture of metals" is almost limitless in its scope under unrestricted interpretation. If the proposal is adopted and the society directs its attention to the treatment of metals and to such phases of their manufacture as are pertinent to their subsequent treatment or use, it will be found the field is sufficiently large to absorb all the energies of members of the organization for years to come.

SOME TRADE PRESS COMMENTS ON CONVENTION

IT IS indeed gratifying to us to read some of the interesting comments made by several of the trade publications in their reviews of the Fifth Annual Convention and Exposition of the American Society for Steel Treating.

In a twelve-page review of the activities of the convention and exposition the *Iron Age* of October 18, says in part, that—

"An organization which can successfully stage a technical convention and exhibition of the high order and magnitude of the

one held in Pittsburgh, October 8 to 12, by the American Society for Steel Treating, at once takes its place in the front rank of societies of this class. That this has been possible after only four years of existence is the striking fact. The event, both from the technical and exhibition standpoint, has become one to be looked forward to with keen interest. Out of a total membership of over 2700 there was a registered attendance of nearly 1500, exceeding any previous meeting. The membership registered at Detroit a year ago was about 1250. In expansion, enviable progress was made in that the net increase in membership in good standing last year was about 18.75 per cent.

"The technical sessions without exception were featured by large audiences and an enthusiasm naturally the accompaniment of a large group of comparatively young men. The papers on the whole compare favorably with those in the programs of some of the much older technical organizations.

"The steel exhibition was the most successful of the kind ever held anywhere and it was also the largest. Entire satisfaction was voiced by nearly all those who had booths, many of them reporting excellent business booked or in prospect. The experiment of not opening the exhibition until afternoon of each day appeared to be a success."

Iron Trade Review

The *Iron Trade Review* of October 18 in a nine-page review of the exposition and convention, makes the following comments:—

"Without reservation the Fifth Annual Convention and Exposition of the American Society for Steel Treating held in Pittsburgh, October 8-12, may be judged the most outstanding yet conducted by that society. Registration reached a total of approximately 1800 of which 1492 were classified as members. Thus on the basis of a total society membership of 3000, the attendance represented almost 50 per cent, a figure probably never before reached by the larger technical organizations.

"Technical sessions in the morning were held at the

William Penn hotel, while the afternoon meetings were conducted at Motor Square Garden, where the exposition was in progress. Attendance at these meetings was unusually large and may be attributed to the facts that no simultaneous meetings were held and the opening of the exposition was arranged so as to offer little interference to the operation of the program. Motor Square Garden is located six miles from downtown Pittsburgh, but in spite of this, the attendance there broke all previous show records, it being estimated that upwards of 40,000 people passed through during the five days. Two floors were devoted to the exhibits which represented a considerably wider range of equipment than last year. The total floor space was about one-third larger than in 1922, nevertheless it was necessary to refuse many applications."

Chemical and Metallurgical Engineering

Chemical and Metallurgical Engineering in its October 22 issue devoted four pages to a review of the exposition and convention. A part of this review is as follows:—

"The Fifth Annual Convention and Exposition of the American Society for Steel Treating at Pittsburgh the week of October 8 was a great success from every viewpoint. It was well attended, the papers presented at the technical sessions were excellent and the discussions following these papers were lively. The exposition was one-third larger than last year and was visited by 60,000 persons.

"The steel exposition was held at Motor Square Garden, which, though 6 miles from the William Penn hotel, the convention headquarters, proved to be an excellent building for such an exhibit. Gas, air and electricity were available, and consequently a large portion of the exhibit consisted of actual industrial operations. Real progress in heating methods, testing methods, control devices, heat-resisting metals and other refractories was evident."

FIFTH ANNUAL CONVENTION AND EXPOSITION

BEYOND all fear of contradiction, the Fifth Annual Convention and Exposition of the American Society for Steel Treating held in Pittsburgh, Oct. 8 to 12, was an unqualified success. From the standpoint of the quality and number of exhibits at the exposition, the high quality of technical and practical papers presented at the technical sessions, and the unprecedented attendance of members and guests, mark this convention as unequalled by all previous ones.

The members of the Pittsburgh chapter are to be congratulated upon the very successful way in which they did their part toward the success of the convention and exposition. It was largely due to the untiring efforts of all of the Pittsburgh chapter members that the convention and exposition was such a decided success, proving to be of great interest not only to the technical man but to the practical man as well.

The number and variety of exhibits at this convention was fully one-third larger than the number exhibiting at the Detroit convention last year, and the amount of floor space used in presenting the exhibits was fully 50 per cent larger than that used last year. The exhibits were assembled on the main floor and subfloor of Motor Square Garden, the booths in the subfloor having an Egyptian setting. One of the main features of the subfloor was that of an exact replica of the tomb and mummy of the ancient Egyptian ruler, King Tutankhamen. The main floor was very artistically decorated and presented a most attractive and pleasing picture. Many live exhibits were in operation. Music was furnished both afternoon and evening by a large band on the main floor and by an orchestra on the subfloor.

For those who were unable to be in attendance at the Pittsburgh convention, an outline of the activities undoubtedly will be of interest. The principal technical papers were presented at the morning sessions in the ball room of the William Penn hotel. The exhibition hall was open in the afternoon and evening only, so that the members and exhibitors might have the opportunity of attending the technical meetings. The opening meeting and first technical session was held at 10 a. m. on Monday, Oct. 8, at which time W. J. Merten, chairman of the Pittsburgh chapter presided. After

an address of welcome by Mr. Merten, J. Trautman Jr., general chairman of the Pittsburgh chapter convention committees gave an address of welcome on behalf of the committee; following Mr. Trautman was H. M. Irons, representative of Mayor William Magee, who welcomed the society to Pittsburgh. A. L. Humphrey, President of the Pittsburgh Chamber of Commerce then gave an address of welcome on behalf of the industries of Pittsburgh. President Tillman Danis Lynch of the American Society for Steel Treating then gave a speech in response to the previous speakers, thanking them for their very cordial welcome to the Steel City. After the preliminary speeches, the meeting then entered into its technical session, the program consisting of the following papers:

The Manufacture of Automobile Leaf Springs—C. G. Shontz, metallurgist, Perfection Spring Co., Cleveland. (Presented by title.)

Metallography and Testing of Oxyacetylene Welds—J. R. Dawson, research metallurgist, Union Carbide & Carbon Research Laboratories, Inc., Long Island City, N. Y.†

Some Observations on Furnaces and Fuels, Including the Electric Furnace for Heat Treating—E. F. Collins, consulting engineer, General Electric Co., Schenectady, N. Y.

The Tempering of Tool Steels—J. P. Gill and L. D. Bowman, metallurgists, Vanadium-Alloys Steel Co., Latrobe, Pa.

Abnormal Grain Growth in Cold-Rolled Low-Carbon Steel—V. E. Hillman and F. L. Coonan, metallurgist and assistant metallurgist, Crompton & Knowles Loom Works, Worcester, Mass. (Presented by title.)*

The official opening of the exhibition was at 1 p. m. All registration of members and guests took place at Motor Square Garden. At 3:30 p. m. the afternoon technical session was held in the meeting room at Motor Square Garden. The program for this technical session is as follows:

The Annealing of Sheet Steel—Francis G. White, metallurgical engineer, National Enameling & Stamping Co., Granite City, Ill.**

Automobile Sheet Steel Specifications—H. M. Williams, metallurgist, General Motors Research Corp., Dayton, O.

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†Published in October, 1923, TRANSACTIONS, page 467.
*Published in August, 1923, TRANSACTIONS, page 162.
**Published in August, 1923, TRANSACTIONS, page 121.

Tuesday, Oct. 9

Tuesday morning at 9:30, the morning technical session was opened by the chairman, A. H. d'Arcambal. The program for this session was as follows:

Measurement of Carbon Penetration in Carburized Steels—S. P. Rockwell, consulting metallurgist, Hartford, Conn., and Frederick Downs, chemist, New Britain Machine Co., New Britain, Conn.

Case Hardening and Other Heat Treatments as Applied to Gray Cast Iron—H. B. Knowlton, instructor, Central Continuation school, Milwaukee.*

The Influence of Barium Carbonate upon Wood Charcoal Used for Cementation—B. F. Shepherd, Metallurgical department, Ingersoll-Rand Co., Phillipsburg, N. J.

Salt Baths and Containers—Sam Tour, metallurgist, Doehler Die Castings Co., Brooklyn, N. Y.

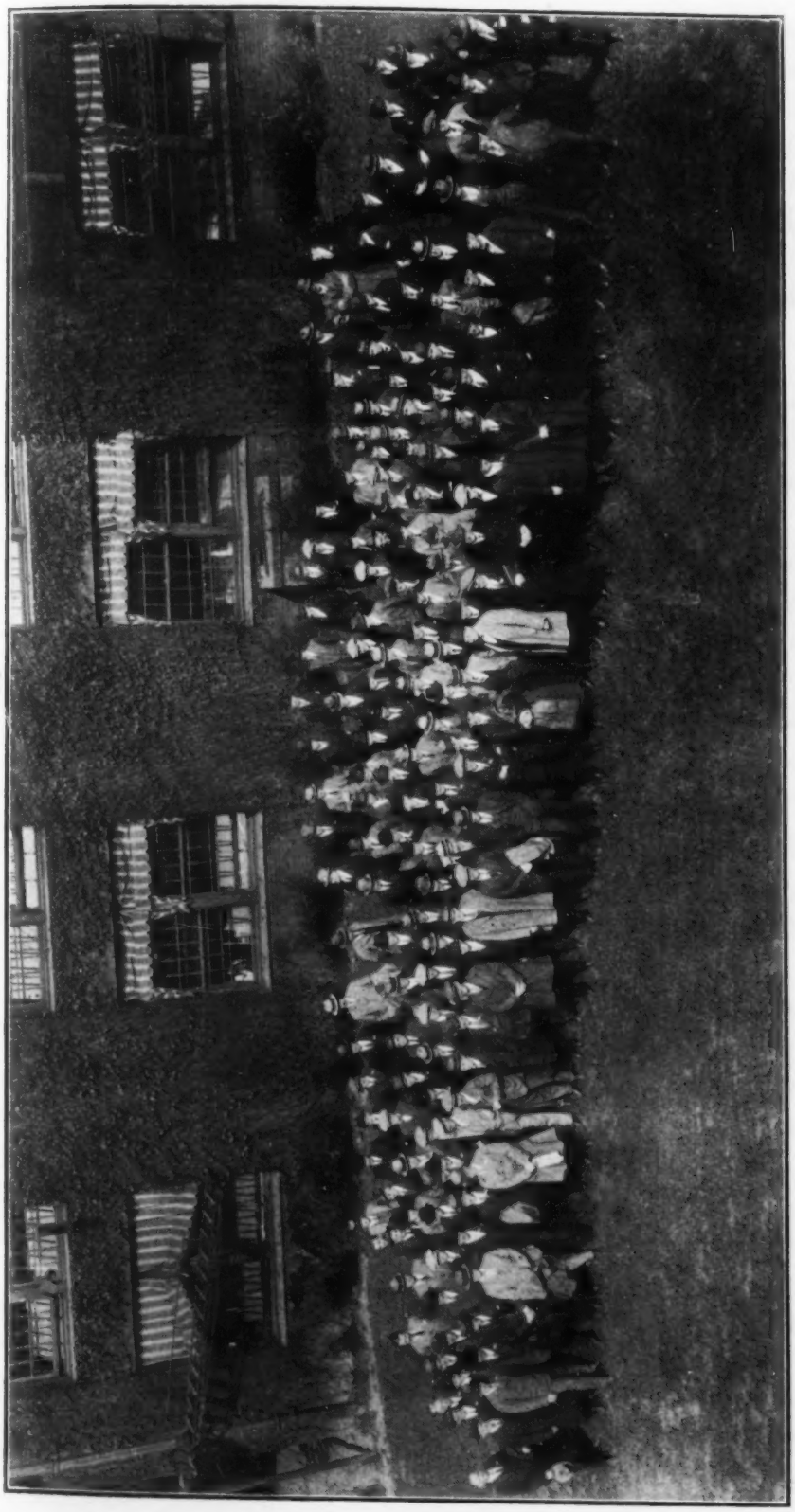
The Thermal Treatment of the Light Alloys of Aluminum and Copper—A. M. Portevin and Francois LeChatelier, Paris, France. (Presented by title.)

At 3:30 p. m. a Round Table discussion under the direction of the Standards committee was called to order by Chairman R. M. Bird in the meeting room at Motor Square Garden. At 9:30 p. m. the annual smoker and entertainment, sponsored by the members of the Pittsburgh chapter was held in the ball room of the William Penn hotel. This entertainment was attended by large numbers of members and guests and the vaudeville stunts which were presented were indeed interesting and entertaining. The members of the American Society for Steel Treating look forward each year to the smoker and we are sure that this year's program did credit to the members in charge of arrangements.

Wednesday, Oct. 10.

The annual meeting of the society was held at 9:30 a. m. on Wednesday, Oct. 10, in the ball room of the William Penn hotel, president T. D. Lynch presiding. As the first order of business, President Lynch requested that each of the chapter delegates arise and announce their names for the stenographer's report. Twenty-four chapters were represented by official delegates.

*Published in October, 1923, TRANSACTIONS, page 494.



The Group of Members and Guests who visited the Westinghouse Electric & Manufacturing Company's plant in East Pittsburgh, Tuesday afternoon, Oct. 9, 1923.

The next order of business on the program was the report from the tellers of election which was read by C. G. Shontz, chairman of the committee. The result of the balloting was published on page 449 in the October issue of TRANSACTIONS. The newly elected officers are as follows: for president, one year, Dr. George K. Burgess, director of the Bureau of Standards, Washington; for second vice president, two years, Robert M. Bird, engineer of tests, Bethlehem Steel Co., Bethlehem, Pa.; for treasurer, two years, Dr. Zay Jeffries, research bureau, Aluminum Co. of America, Cleveland; for director, two years, J. Fletcher Harper, research engineer, Allis-Chalmers Mfg. Co., Milwaukee. After the tellers' report, president Lynch called for the newly elected officers to arise so that they could be officially introduced to the membership.

President Lynch then presented his annual report of the activities of the American Society for Steel Treating for the year 1922-23, which is published in full, commencing on page 571 of this issue of TRANSACTIONS.

Upon the conclusion of the report, the meeting then extended a hearty vote of thanks to President Lynch for his report and very capable leadership during the past year.

The next order of business was the report of J. V. Emmons, national treasurer of the society, who read and interpolated his financial report for the last fiscal year. Mr. Emmons' report is as follows:

"In reporting the financial status of the society, attention is first called to the Certified Financial statement for the year 1922 as published in the TRANSACTIONS of May, 1923. This statement was the most complete ever published by our society and in fact was more complete in detail than any statement that has come to my knowledge from other societies.

"Since the last annual meeting, the sum of $3,000 was set aside by the board of directors for the principal of the Henry Marion Howe Medal fund. The sum of $10,000 was set aside from the proceeds of the 1922 convention as a permanent convention reserve, in order to fortify the society against disaster from a financially unsuccessful convention. The principal of these two funds was invested in United States government bonds.

"During the year 1922, the society not only lived with its in-

come, but made substantial additions to its reserves and surplus.

"At the beginning of the year 1923, the finance committee established a budget of expected receipts and expenditures for the year based upon our experience for 1922. This budget was subdivided by the treasurer into monthly items.

"The following is, therefore, a report of progress for the first eight months of 1923:

"The budget expected receipts, exclusive of convention, for the eight months ending Sept. 1, to be $33,084 with expenditures of $32,559. The actual receipts were $37,270.01 with actual expenditures of $34,963.50. The receipts were, therefore, $4186.01 or 12 per cent above our budget expectations. Our expenditures were $2404.50, or 7.4 per cent above our budget expectations. Our receipts, therefore, increased faster than our expenditures. The surplus on Aug. 31 was $11,406.38 of which $673.25 was miscellaneous accounts receivable, $3011.25 advertising accounts receivable, $2514.24 office furniture and fixtures, $962 inventory of paper and bindery stock, $4245.64 working cash."

The membership unanimously accepted the treasurer's report and extended a hearty vote of thanks to him for the very capable service he rendered during his two years in office as treasurer of the American Society for Steel Treating.

W. H. Eisenman, national secretary of the society then presented his annual report which is published in this issue of TRANSACTIONS, commencing on page 578.

The report of the national secretary was unanimously accepted by the membership and a hearty vote of thanks was extended to him.

The next order of business on the program was the report by Robert M. Bird, chairman of the national Standards committee of the American Society for Steel Treating who reported the treatise on pyrometry by Sub-committee IV, and the tentative recommended heat treating practices for carbon and high-speed tool steels of which Sub-committee I, which appeared in the September, 1923, issue of TRANSACTIONS; likewise he reported the progress made by the other two sub-committees, namely Sub-committee II, that on the general heat treatment of steels and Sub-committee III on case hardening of steels.

Mr. Bird went into considerable detail pointing out some of the difficulties that the various committees had encountered in carrying out their work. He reported that during the round table discussion session held by the Standards committee, on the previous day, many of the problems encountered by the various committees were discussed in detail. He indicated that it was the sense of the round table meeting that the name of the present "Standards

A Booth on the Main Floor of Motor Square Garden
(Courtesy of *Iron Trade Review*)

committee" be changed to "Recommended Practices committee" and that this opinion would be given to the Board of Directors, for consideration.

He also pointed out that the three national societies namely, The American Society for Testing Materials, The Society of Automotive Engineers and The American Society for Steel Treating have definitions of heat treatment terms which are basically in accord with each other but differ in minor details, and in consequence a Tri-Society committee was made up of a representative from the controlling committee of each of these three societies. This Tri-Society committee has met at frequent intervals (and through correspondence) in an effort to establish a uniform set of heat treatment definitions. Mr. Bird said that our representative, John E. Halbing, had reported to the Standards committee that

the Tri-Society committee has been unable to arrive at a conclusion.

Mr. Bird pointed out that there is a vital need for a common set of heat treatment definitions and that it was his opinion that there is no other society or agency under which the work of attaining such a set of definitions falls so properly as it does to the American Society for Steel Treating and it was his hope that the society, would actively undertake this proposition during the next year.

Following Mr. Bird's report a motion was made by A. W. F. Green that it is the consensus of opinion of the meeting that the name of the present "Standards committee" be changed to "Recommended Practices committee" and that this suggestion be transmitted to the Constitution and By-Laws committee. A short discussion was then held concerning the differences in the definitions of various heat treating terms. A vote of thanks was extended to the members of the Standards committee and its Sub-committees for their very capable work during the past year.

The next order of business was the report by S. M. Havens, chairman of the Constitution and By-Laws committee of the American Society for Steel Treating, who outlined in considerable detail the work that this committee has been doing the past year, pointing out that it is advisable for this society to revamp its present constitution so that it would more nearly comply with the laws of the principal states and especially the state of Ohio, under which the Society is incorporated, and as a result the committee had drafted a proposed Constitution and By-Laws which would, if accepted by the membership, replace the one which we are now using. This proposed draft of the new Constitution and By-Laws had been distributed by mail to all members of the society during the month of August. Copies of the "Proposed Constitution and By-Laws" were then distributed among the members for ready reference in respect to the various changes therein and Mr. Havens then took up, point by point, the principal variations from the present constitution, for the purpose of discussing them. He pointed out that these proposed changes in the constitution are not in their final form but were submitted as suggestions for the discussion and approval or rejection by the membership. He indicated that while the Board of Directors had approved the draft

as it now stands, the matter of adopting it rests entirely with the membership and that it should be very carefully considered and discussed prior to its adoption.

Considerable discussion was held in reference to the changing of the Society's name due to the fact that the object of the Society which originally pertained to "the promotion of the arts and sciences connected with the treatment of iron and steel" had been proposed to read "the promotion of the arts and sciences connected with either the manufacture or treatment of metals, or both." With this change in the object of the Society activities to include metals other than iron and steel it was suggested that the Society's name likewise be broadened. Such names as the American Society for Metal Treating, the American Metallurgical Institute, the American Society for Steel Treating and Metallurgy, etc., were suggested. The majority of those present at the meeting considered it inadvisable to make any change in the name of the Society at the present time.

Considerable discussion was held pertaining to Article 10 of the proposed constitution relating to the number of officers and the Board of Directors of the Society. The delegates from the Detroit chapter proposed certain changes with reference to the method of the selection of the national Nominating committee. After considerable discussion the Detroit delegates withdrew their proposals.

Some discussion pertaining to the selection of the Nominating committee ensued and a motion was then made and carried that it was the consensus of opinion of the assembled members, that representation on the national Nominating committee of the American Society for Steel Treating should be by chapters, that is, each chapter of the Society should be represented on this committee. It was further moved and approved by the meeting that only one representative from each chapter should have membership on the Nominating committee. These motions were in the form of recommendations to the national Constitution and By-Laws committee, with authority to work out the details necessary for proper application of the principle involved.

The Wednesday afternoon technical session was held in the meeting room of Motor Square Garden at 3:30 under the chairmanship of J. J. Crowe. The program for this session was as follows:

The Manufacture of Heavy Forgings—W. R. Klinkicht, foreman, heat treating department, Pollak Steel Co., Cincinnati.

Determining Heat Treating Costs—H. F. Wood, metallurgist, Wyman-Gordon Co., Ingalls-Shepard division, Harvey, Ill. (Presented by title.)

Practical Heat Treatment of Carbon, Alloy and High-Speed Steel Tools—J. J. Jones, metallurgist, Pittsburgh.

Spark Testing of Steel—Don Stacks, consulting metallurgical engineer, Hartford, Conn. (Presented by title.)

Some Fundamental Defects of Hardened Steel—Dr. Leslie Aitchison, Birmingham, England. (Presented by title.)

At 9:30 p. m. the annual informal dance of the Society was held in the Ball room of the William Penn Hotel. This party was very well attended and all spent a very delightful evening.

THURSDAY, OCT. 11

The morning technical session was held in the Blue room of the William Penn Hotel and was called to order at 9:30 by Professor H. M. Boylston. The following papers were presented at this session:

*Effect of Heat Treatment on Lathe Tool Performance and Some Other Properties of High-Speed Steels,** by H. J. French, Jerome Straus and T. G. Digges was presented by H. J. French, physicist of the Bureau of Standards.

Secondary Hardness in Austenitized High Chromium Steels, was presented by E. C. Bain, research metallurgist, Atlas Steel Corp., Dunkirk, N. Y.

*The Hardening of Steel,*** by Dr. Zay Jeffries and R. S. Archer, Research Bureau, Aluminum Co. of America, was presented by Mr. Archer.

Crystallization of Iron and Its Alloys, by Professor Albert Sauveur, professor of metallurgy, Harvard University, was presented by title.

Experiments on the Effect of Temperature on the Impact Resistance of a Low-Carbon Steel Which Has Been Worked or

*Published in September, 1923, TRANSACTIONS, page 353.
**Published in September, 1923, TRANSACTIONS, page 263.

Deformed at Different Temperatures by N. Richardson and E. K. MacNutt, Watertown Arsenal Metallurgical Laboratory, was presented by title.

At 2:30 p. m. the Hardness Testing Symposium under the auspices of the National Research Council and the chairmanship of A. E. Bellis, was held in the meeting room at Motor Square Garden. The following papers were presented. All but the first one was published in the September issue of TRANSACTIONS:

The Herbert Pendulum Hardness Tester—E. G. Herbert, England.

The Hardness of "Common High" Sheet Brass—A. L. Davis, metallurgist, Scovill Mfg. Co., Waterbury, Conn.

Magnetic Indications of Hardness and Brittleness—A. V. deForest, Research department, American Chain Co., Bridgeport, Conn.

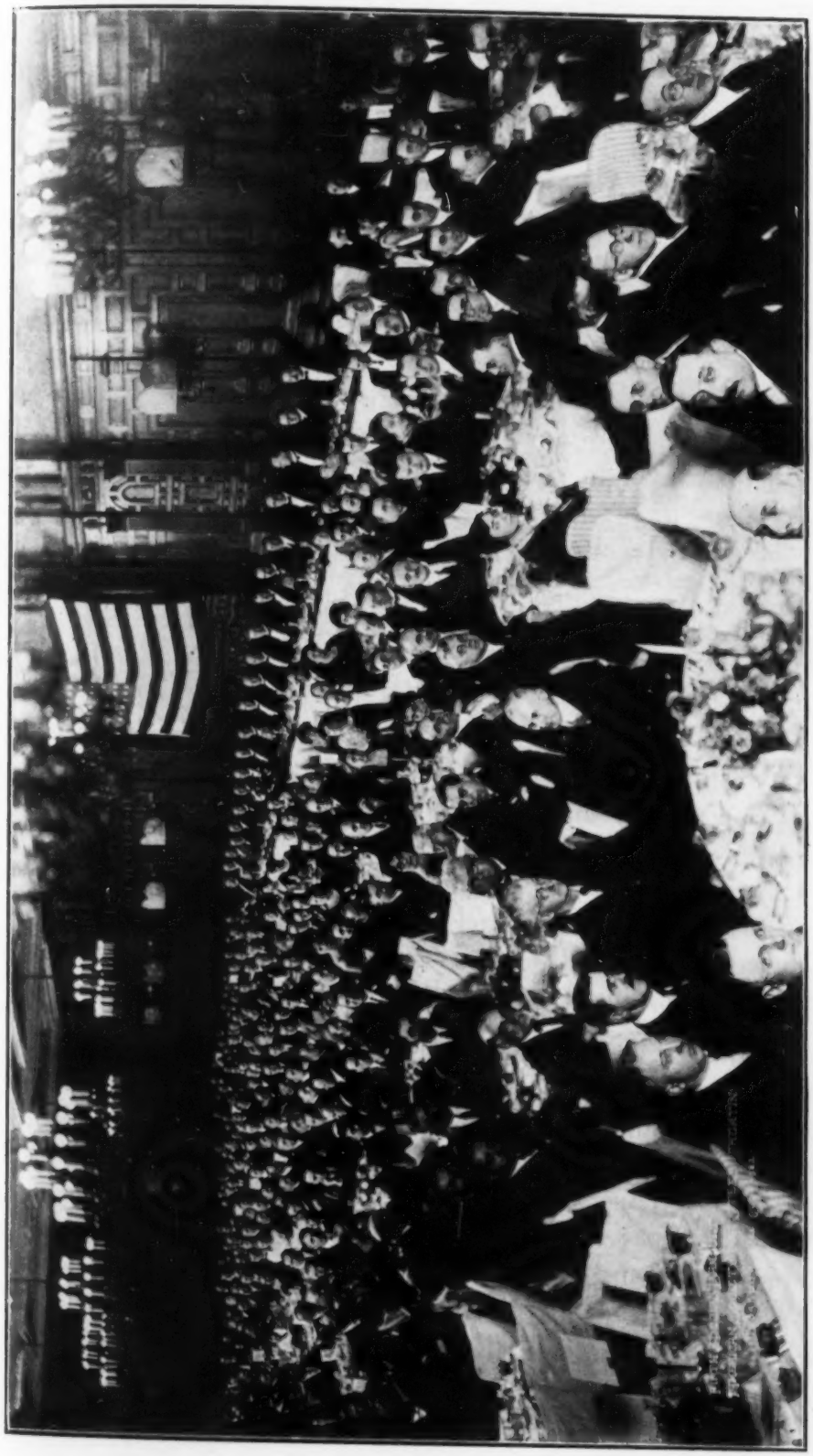
Testing of Steel for Hardness—H. M. German, metallurgist, Henry Disston & Sons, Inc., Philadelphia.

The exposition closed at 5:30 p. m. and the annual banquet of the Society was held during the evening in the English room of the Fort Pitt Hotel. This banquet was exceedingly well attended as evidenced by the accompanying photograph. At the speaker's table were seated the officers and guests of honor of the Society including Governor Gifford Pinchot and Captain Irving H. O'Hay. After the dinner had been served President Lynch opened the meeting with a few remarks and then introduced each of the newly elected officers.

PRESENTATION OF THE FIRST HENRY MARION HOWE MEDAL TO MRS. HOWE

President Lynch made the following remarks in presenting the first medal to the Society's honored guest, Mrs. Henry Marion Howe, widow of our esteemed and beloved Honorary member, Doctor Henry Marion Howe:

"The Board of Directors of the American Society for Steel Treating realize that man needs special incentive to develop and prepare for publication new and useful ideas. They also realize that one of the best incentives for this type of work is something that brings to an author recognition and honor. They have, therefore, made provision for an honor gold medal to be known as the



Fifth Annual Banquet of the American Society for Steel Treating, English Room, Fort Pitt Hotel, Oct. 11, 1923

Henry Marion Howe Medal. This medal is to be awarded to the author of the paper which shall be judged to be of the highest merit.

"All papers in order to be considered must be published originally in the TRANSACTIONS of the Society, during the twelve months ending August 1 of each year in which the medal is awarded.

"The competition for the Henry Marion Howe Medal shall be open to all. The award shall be made by the Board of Directors. The award may be withheld at the discretion of the Board of Directors.

"Dr. Henry Marion Howe in whose honor this medal is given was a son of a noted physician of research type who was also a great philanthropist. His mother, Julia Ward Howe, was a leader in the abolition of slavery and is perhaps best known to the American people as the author of the *Battle Hymn of the Republic*.

"Dr. Howe was so well known and received degrees and honors from so many and varied sources that it is only possible to mention a few.

Elliott Cresson Gold Medal, Franklin Institute—1895.

Bessemer Medal, British Iron and Steel Institute—1895.

Chevalier Legion d'Honneur of France—1900.

Knight of Stanislas, Russia—1906.

John Fritz Medal—1917.

"He was widely known through his scientific books and technical papers today universally accepted as text books, a constant attendant at our meetings and his contributions to the discussions were always timely and stimulating. He was a master in presiding over and directing meetings—in expressing his thoughts in simple, forceful language—a man of keen vision and power of observation—a friend and an inspiration to all who knew him.

"On behalf of the Board of Directors, I have the honor of presenting the first medal, struck in bronze, from the die from which the gold medal is made to Mrs. Henry Marion Howe, who

was recognized by Dr. Howe as an inspiration and co-worker, and who always accompanied him in his travels in this country and abroad.

PRESENTATION OF THE HENRY M. HOWE MEDAL TO MR. JANITZKY

"On behalf of the Board of Directors, I have the honor of presenting the first Henry Marion Howe Gold Medal for 1922 to Emanuel J. Janitzky for his paper, entitled, the *Influence of Mass in Heat Treatment.*"

The Henry Marion Howe Medal*

The meeting was then turned over to the toastmaster, George H. Neilson, who presented the awards to those school children contestants who had won honors in the recent essay writing contest conducted by the Pittsburgh Post and the American Society for Steel Treating, pertaining to the steel industry of Pittsburgh.

Toastmaster Neilson then introduced the speaker of the evening, Captain Irving H. O'Hay, hero of many wars and the hero of Richard Harding Davis' novel, "The Soldier of Fortune." Captain O'Hay served in the World war with the "Princess Pats" and later with the American Expeditionary forces. Captain O'Hay gave a wonderfully interesting talk upon his adventures around the world, combining humor and wit with facts and conditions of life as he finds them.

Governor Pinchot having arrived later in the evening was

*The Society wishes to acknowledge the valuable courtesy of R. Wallace and Sons Manufacturing Co., of Wallingford, Conn., for the designing and striking of the Henry Marion Howe Medal, and to the Keller Mechanical Engineering Corp. of Brooklyn for the preparation of the model and the cutting of the dies.

then introduced and gave a brief address pertaining largely to the political situations in the state of Pennsylvania.

W. H. Eisenman, national secretary of the American Society for Steel Treating then extended words of appreciation and thanks to the various Convention committees and to the entire membership for their loyal support in making the Fifth Annual Convention a success. In closing he announced the presentation of a medal to be known as the Past-President's Medal to the retiring president, Tillman Danis Lynch.

The meeting adjourned at 11:30 p. m.

Friday, Oct. 12

The Friday morning technical session was held at 9:30 in the Ball room of the William Penn Hotel, Dr. Paul D. Merica, being chairman of this session. The technical papers program for this session was as follows:

Carbon and Carbon-Vanadium Steel Castings—A Comparsion—J. M. Lessells, mechanical engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Investigation of the Treatment of Steel for Permanent Magnets—R. L. Dowdell, Instructor in Metallography, University of Minnesota, Minneapolis.

Protective Coatings for Selective Carburization—J. S. Vanick and H. K. Herschman, metallurgist and assistant physicist, Bureau of Standards, Washington.*

The Physical Properties of Metals at Elevated Temperatures—Vincent T. Malcolm, metallurgist, Chapman Valve Mfg. Co., Indian Orchard, Mass.

The Seasoning of Steel—W. P. Wood, Department of Metallurgy, University of Michigan, Ann Arbor, Mich.**

Conical Illumination in Metallography—H. S. George, Union Carbide & Carbon Research Laboratories, Inc., Long Island City, N. Y.†

The Theory in Quenching Steels—Kotaro Honda, Tohoku Imperial University, Sendai, Japan. (Presented by title.)††

At 2 p. m., the Symposium on Metallurgical Education was

*Published in September, 1923, TRANSACTIONS, page 305.
**Published in October, 1923, TRANSACTIONS, page 488.
†Published in August, 1923, TRANSACTIONS, page 140.
††Published in October, 1923, TRANSACTIONS, page 450.

held in the meeting room at Motor Square Garden under the chairmanship of Professor S. L. Goodale. Considerable interest has been shown in this annual symposium and it is felt that as evidenced by this interest it is a session which should be fostered and held each year during the Annual Convention.

At 4:30 p. m. Committee A-4 of the American Society for

A Booth on the Main Floor of Motor Square Garden
(Courtesy of *Iron Trade Review*)

Testing Materials under the chairmanship of Professor H. M. Boylston held a meeting at Motor Square Garden.

At 10 p. m. the exposition officially closed.

Plant Visitation

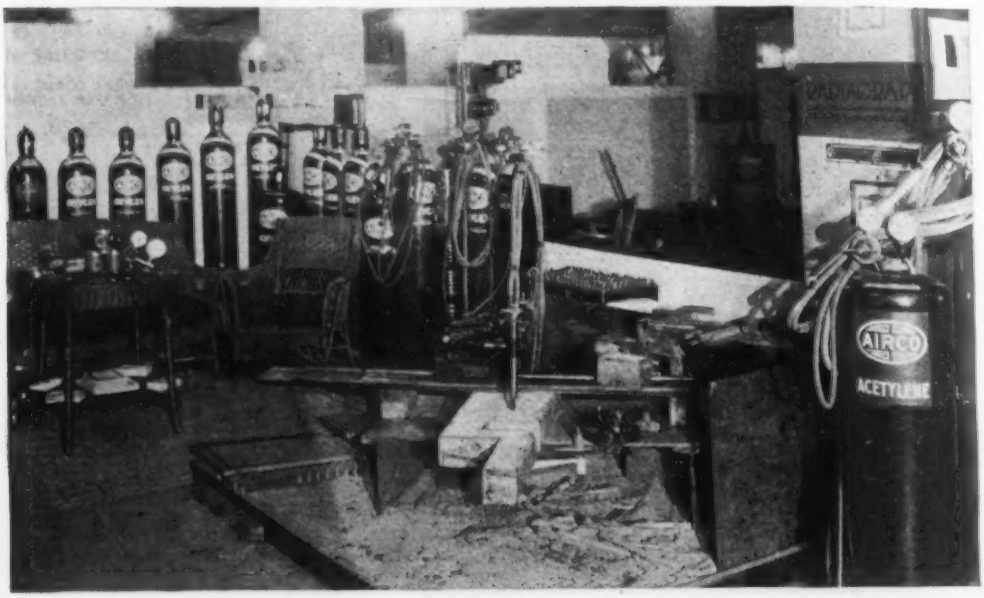
Many members and guests availed themselves of the opportunity of visiting various plants in and around Pittsburgh. The plants which were officially scheduled for visitation were the Westinghouse Electric & Mfg. Co. on Tuesday afternoon, the Homestead Works of the Carnegie Steel Co. on Wednesday afternoon and the National Tube Works, McKeesport, Pa., on Friday afternoon. All of these plant visitations were very well attended and proved of great interest to those who had the privilege of attending.

Visiting Ladies Entertainment

The visiting ladies were royally entertained by the Pittsburgh

Entertainment committee under the chairmanship of J. A. Succop, and the ladies auxiliary committee and they enjoyed many hours of sight-seeing in and around Pittsburgh.

The ladies registered immediately upon their arrival in Pittsburgh for the purpose of indicating those activities in which they desired to participate. The first activity was a luncheon served



A Booth on the Sub Floor of Motor Square Garden
(Courtesy of *Iron Trade Review*)

on Monday, Oct. 8 at 1 p. m. in the Blue Room of the William Penn Hotel. This was followed by an auto ride through the city. In the evening the ladies visited the exposition at Motor Square Garden. Tuesday afternoon the ladies were entertained at a tea at the Margaret Morrison Home, Carnegie Institute. In the evening they were entertained at a theater party. Wednesday morning at 10:00 the ladies visited the H. J. Heinz Company's pickle factory and after exploring the factory had luncheon there. Wednesday evening they attended the annual dance of the Society in the Ball Room of the William Penn Hotel. Thursday afternoon was devoted to a reception to Mrs. Henry Marion Howe, while in the evening they attended the annual banquet of the Society which was held at the Fort Pitt Hotel.

From all reports the ladies had a most enjoyable time throughout the week.

THE PRESIDENT'S ANNUAL ADDRESS

TILLMAN DANIS LYNCH

Introduction

The American Society for Steel Treating has added another year of progress to its history. Its accomplishments are not all that we could wish, but as we must learn by experience, we trust that our shortcomings may be a signal and our achievements an inspiration for a higher and nobler plane of activities.

Our society's goal is worthwhile, its field of activity is unique and it has a very important task to perform by combining our thoughts and experiences for the advancement of not only our membership but to serve mankind.

Let us review briefly the activities of the year. These activities are effective through our chapters, our committees, our national board and the TRANSACTIONS. Our chapter meetings give us the personal work and individual contact which results in co-ordinated efforts. Our committees are instruments for bringing into more constructive and definite form such general information, recommended practices and standards as will assist our membership, advance our organization and establish permanently the work that is accomplished.

Membership

Our membership continues to grow, as is shown by our National Secretary's report with 18.7 per cent increase for the year.

It has been the purpose and policy of the directors to recognize in our membership only those who take some part in the Society's activities, at least that of assisting in its support. This membership list is, therefore, a real one, including only those who are in good standing or whose dues are in no case more than 3 months in arrears.

Chapters

Our chapters are 28 in number, the same as last year. The chapter at Bridgeport, Conn., has been discontinued and a new

one has been organized at Los Angeles, Cal. Reports from this new chapter are very encouraging and its members are showing a healthy active spirit.

The chapters, in general, are demonstrating the good that comes to our members from personal contact, exchange of ideas and experience and the work accomplished by each chapter and its members is in direct proportion to the activity of its members in taking advantage of the opportunities thus afforded to discuss both the personal and general problems taken up.

In former years, the president visited all chapters, but this year a different plan was tried out, viz., each member of the Board of Directors was assigned two or more chapters to visit officially and to make a written report to the Board. These reports give the personnel, financial condition and activities of the various chapters.

It is estimated that the attendance at our chapters for the year has been more than 20,000—a good demonstration of the opportunity given to our members and friends to profit by the exchange of ideas.

Sectional Meetings

There have been two sectional meetings held during the year, one with the Chicago chapter in February and the other with the Lehigh Valley chapter in June. The programs for these two meetings were prepared by the respective chapters and the papers presented were of the highest type. Visits were made to local manufacturing plants where members were shown special courtesies. These meetings brought together many men from different chapters and especially those members located nearest the chapter where these meetings were held, who would not otherwise have been brought together; and the great interest shown, indicates that these sectional meetings should be continued.

It has become apparent however that some of the smaller chapters have refrained from having sectional meetings held in their locality on account of the added cost of such a meeting to the chapter. The Board has therefore decided that the national office should provide for the expense incidental to

the holding of at least two sectional meetings each year and it is hoped that no chapter will refrain from entertaining a sectional meeting on account of the cost.

Committees

Some of our National committees have done splendid work while others have not been especially active. The Standards committee is an example of one that has done a real work.

The planning of this committee was a little different from that of former years.

The main membership was made up of a general chairman and four members. Each member was made chairman of a sub-committee on recommended practices of an assigned subject. These sub committees were localized in limited zones to enable them to get together as separate working committees.

Sub-Committee I—Treatment of Tool Steel—W. J. Merten, Chairman, was located in the Pittsburgh district. Their report is published in September, 1923, TRANSACTIONS and is real evidence of work done.

Sub-Committee II—Treatment of Steels General (not including Tool Steel)—F. E. McCleary, Chairman, located in Detroit district. A progress report is made.

Sub-Committee III—Case Hardening—R. J. Allen, Chairman, located in New England. A progress report is made.

Sub-Committee IV—Pyrometry—J. H. G. Williams, Chairman, located in Philadelphia district. This report is published in September, 1923, TRANSACTIONS and includes "Notes on Thermoelectric Pyrometers and Instructions for Their Use in Heat Treating Steel." The data given in this document is beyond doubt the most thorough and comprehensive so far in print, and this society may well be proud to have fostered its production.

Finance Committee

The Finance committee has, during the past year, exercised general supervision over the financial policies of the society. It supervised the closing of the books for the fiscal year of 1922 and recommended to the Board of Directors suitable

charges to be made for depreciation and bad debts. It made recommendations as to the amount and investment of the various reserves of the society which were in general approved by the board. It recommended and upon approval by the board put into effect a more equitable distribution of office expenses.

The committee caused the books of the Secretary and Treasurer to be audited by a certified public accountant, a copy of their certificate being published in the May, 1923, TRANSACTIONS.

It prepared a budget for the year 1923 which, after minor changes, was approved by the Board of Directors. The committee gave careful supervision over the operation of the budget which has been adhered to within very close limits.

This committee, as you will note, has given its efforts to providing solidarity and security of our funds.

Constitution and By-Laws Committee

The constitution and by-laws committee was commissioned by the Board of Directors to revise and rewrite the constitution and by-laws of the society. This committee has given much time and painstaking thought to this work, resulting in a rewritten document. The entire Board gave a full day to its consideration section by section before ordering it to be printed and sent to the membership in a tentative form for their comments and constructive criticisms. It is hoped that the membership at large will render all possible assistance in making this document just what it should be. Mr. Havens, the chairman of the committee, will make a progress report at this convention.

The Board of Directors has held five meetings during the year 1922-1923, the first at Detroit at the close of the convention to talk over the general plans for the year; and the second at the national office, Cleveland, Ohio, on Oct. 27 at which time the eight standing committees and four sub-committees were appointed.

A number of committees have been appointed during the year to co-operate with other organizations, namely National Research Council, Division of Engineering, War Department, United States Army, Advisory, Bureau of Standards, Bureau of

Mines, Drill Steel Investigation, On Nomenclature with American Society for Testing Materials, Society of Automotive Engineers, Sub-Committee XIV of Committee A-1-American Society for Testing Materials on Tool Steel, National Research Council, Instrument Manufacturers and Users.

The third meeting was held at Chicago on Feb. 9 during the sectional meeting; the fourth meeting at Bethlehem on June 16 during the sectional meeting and the fifth at Pittsburgh during the convention.

These meetings have been scheduled so as to accomplish the greatest benefits for the good of the society with the least amount of time and mileage.

All members of the Board have been in attendance at each of these meetings.

Transactions

Our TRANSACTIONS have continued to improve under the supervision of our editor—Ray T. Bayless, and the Publication committee of which Prof. H. M. Boylston is chairman.

They are striving continually to improve the tone of TRANSACTIONS by being more and more exacting in the question of acceptance of manuscripts.

Our Editor has devised a scheme of trimming cuts so as to reduce the cost of publishing without interfering with the proper illustration of the paper.

Each issue includes one or more editorials on general affairs of interest to our members.

Beginning with the July, 1923 issue, a new style of type page has been used which is a very marked improvement.

Our TRANSACTIONS is now recognized as one of the best if not the best publication of its kind. The papers published in recent issues and being presented at the convention represent the rapid progress that is being made and provide for our membership an encyclopedia of up-to-the-minute refinements in the art and science of heat treating metals.

Data Sheets

The problem of preparing data sheets has been given much thought. The National Secretary's report will show the progress made.

Annual Convention

The annual convention and exposition at Detroit last October set up a standard that will be difficult to excel. The *Iron Age* gave expression in their issue following the convention which expresses the general opinion most admirably, namely: "An unqualified success was the general verdict of those who attended the fourth annual convention and exposition of the A. S. S. T. The record made by the society, only three years old, both in technical papers and in exhibits, insures it a place among the leading technical organizations in the country and stamps its annual meeting as one to be looked forward to and to be reckoned with."

The Pittsburgh Convention is now a reality, it is 100 per cent educational and it has drawn its papers from among the best talent in this country and also from England, France and Japan.

The Pittsburgh Exposition covers 33 per cent greater floor area than any previous exhibition and the quality and character of the exhibits were never better. We are advised that this is the first time that both floors of Motor Square Garden have been fully occupied. The Board of Directors has made a change, this year, in the method of financing the convention. The exhibition has been planned on a self-sustaining basis and an entertainment fund has been provided from the rental receipts so that special donations from local chapters will not be necessary. This plan has in general been carried out by our National Secretary assisted by the local committees.

The chairman of our local convention committee has instituted a feature that is worthy of special mention. He has arranged for each member of the Pittsburgh chapter to wear a badge with the words "AT YOUR SERVICE" printed thereon. Let this emblem remind us that we should all help to conduct the affairs of this organization so that through us, it may fulfill the law of service. May we each be mindful of the fact that we are put upon this earth to be of service to each other and to work out the great plan of life. God never made a loaf of bread, but he made man, a field, and gave us seeds to sow.

God never made a coat, but he gave us the sheep to grow wool and the art of spinning and weaving.

God never made steel, but he gave us iron ore, limestone and coal.

These raw products are ours to use and steel is ours to heat treat according to the laws so natural and so definite.

What are we doing as individuals and as an organization to be of real service in working out the great plan of which we form a part? Let our efforts be co-ordinated with the efforts of others so that we may continue to be of service one to the other and all to the fulfillment of this plan.

Conclusion

In concluding this term of office, as your President, I desire to express my appreciation for the support so freely and effectively given by our members at large, our committees, our chapters and our Board of Directors. All have given much of their time and talent to the affairs of the society. Last but not least, I appreciate the loyal and untiring efforts of our staff whose full time is devoted to the society work and which has made it possible to carry on not only the extensive work at the national office but to edit and publish our TRANSACTIONS and carry on so successfully the big task of managing, in conjunction with our local committees, our annual convention and exhibition.

It is only by the united efforts of all, guided by the special efforts of your officers and directors elected to serve you that our society can continue its growth and high standing among the national associations.

ANNUAL REPORT OF THE SECRETARY

WILLIAM HUNT EISENMAN

The Secretary is pleased to present his annual report which will show that the American Society for Steel Treating has had another successful year.

The majority of members of the American Society for Steel Treating measure true value not by what they get, but by the service they are able to give, and they are all happy at the opportunity of sharing their success with others. They find the greatest satisfaction in knowing they have been of service to the society and to other members. Many nonmembers are perfectly well satisfied to enjoy the benefits provided for them by others and are unwilling to do any part in elevating or maintaining the standard of a profession in which they are engaged. It may be true of some, but fortunately not of many, that they have no ambition for personal advancement and care little about increasing their own efficiency or in the development of the arts and sciences for which the society stands.

Meetings

The sectional and annual meetings of the society continue to grow in importance and usefulness. The Chicago sectional meeting showed a registration of nearly 200, and the sectional meeting at Bethlehem showed a healthy registration of 167 members, while the registration at the annual convention at Detroit last year represented over 40 per cent of the membership and was recognized at that time as being unparalleled in the history of American technical societies, that such a large percentage of the members should be enrolled as being present at a national convention. The meetings of the local chapters have continued to grow in importance and in general benefits to the membership and to increase the prestige of the local and national society.

Too much credit cannot be given to those individuals who have presented papers before the various chapters, sectional and annual meetings, for the large amount of work and effort that have been necessary to properly present their subject to the technical and the nontechnical members present.

Probably the larger percentage of those in attendance at the

chapter meetings are not members of the society, as is shown by the fact that in the 226 meetings held last year the attendance has been in the neighborhood of 23,000. While there are no accurate figures on the percentage of visitors at these meetings, nevertheless, it is a conservative estimate that probably 40 per cent represent men who are interested in the American Society for Steel Treating but not members of the society. Nevertheless, the various chapters have made it a point to extend a cordial welcome to those nonmembers present because it is realized that they are the seeds for future growth in our membership.

Memberships

On the recommendation of the delegates at their annual meeting at Detroit last year the national officers arranged a membership and attendance contest between the chapters of the society.

The membership and attendance contest closed on June 30, 1923 with the following results:

First Prize	$200.00	Tri City	127.6 per cent
Second Prize	150.00	South Bend	99.3 per cent
Third Prize	100.00	New Haven	85.8 per cent
Fourth Prize	50.00	Cincinnati	65.5 per cent

The nearest to Cincinnati was the Northwest chapter with 56.4 per cent and Syracuse with 55.5 per cent.

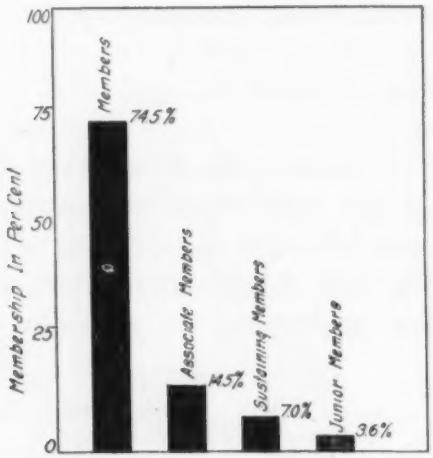
It was quite evident from the number of chapters participating in the contest and the results obtained that it was very interesing and helpful. However, as the contest progressed it was observed that the smaller chapters had a certain advantage over the larger chapters, inasmuch as they required a smaller number not only of new members but of those in attendance at meetings to give a higher percentage.

There are at the present time in the American Society for Steel Treating 2746 members of which 2048 or 74.5 per cent are of the member classification; 400 or 14.5 per cent are associate members; 191 or 7 per cent represent sustaining memberships; while 99 or 3.6 per cent represent junior memberships. There are 6 honorary and two founder members.

Membership in the society during the period from September 1922 to September 1923 showed a gain of 18.75 per cent. On Sept. 1 of last year there were 2313 members. During the year

there has been a net gain of 433 members so that the total membership on Sept. 1, 1923 of bona fide paid-up members is 2746.

There is an excellent opportunity for additional and valuable work to be done in increasing the number of junior members in the society. This work did not start with any effectiveness until the year of 1922 and at the present time is showing gradual improvement. The larger portion of the junior members was secured during the fall of 1922 and spring of 1923. Inasmuch



Graphical Representation of Membership as of Sept. 1, 1923.

as the dues are but $2.50 for the junior members and entitles them to receive the publications of the society and attend chapter meetings, it is a very valuable proposition for the junior and secures his present and future interest in the society.

It is interesting to note that during 1922 and 1923 136 of the 191 sustaining members were added to the list. This was the result of action by the board of directors whereby all but $6.50 of the dues of the sustaining member is returned to the local chapter, so that the sustaining member of a local chapter becomes in reality what the name suggests and they assist materially in financing the chapter programs, and thus have aided greatly in placing many chapters in a better financial position.

About 300 members of the society are serving on more than forty technical and administrating committees in the preparation of standards, reports, professional papers, meetings, research work and the dissemination of literature for the advancement of the

metallurgical profession and the steel industry. Of this number about one-half are on national committees and the other half serving on local committees. The ready response of the entire membership to notices of appointment on various committees as well as their acceptance of the additional obligations and duties entailed, explains one of the reasons for the remarkable success of the American Society for Steel Treating. The membership as a whole is more than willing to do its share of work and to contribute, so far as the individual's abilities permit, in furthering the worthy aims and purposes of the organization.

Publications

Probably the greatest advancement in any publication representing a technical society made in any one year was in the TRANSACTIONS of the American Society for Steel Treating. This has

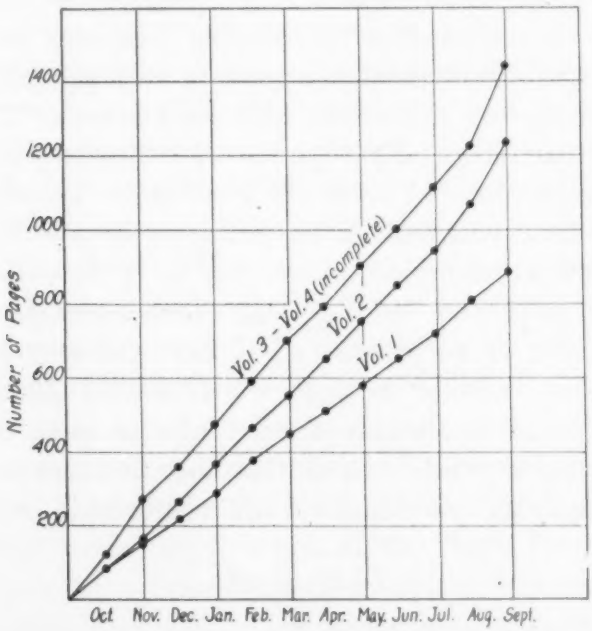


Chart Showing the Progress Made in the Number of Editorial Pages in TRANSACTIONS

been due entirely to the efficient efforts of R. T. Bayless, editor, and the publication committee under the able chairmanship of Professor H. M. Boylston. The size of the type page as well as the spacing between lines have been changed in order to give the TRANSACTIONS a better appearance and greater readability. At the same

time more careful attention has been given to the redrawing of charts and arrangement of material in the adoption of a standard style, so that the publication is regarded with most favorable consideration. There is one file in National headquarters that contains countless letters of commendation and congratulations upon the high position the TRANSACTIONS has taken both in the make-up and contents under the capable direction of Mr. Bayless.

Beginning with Volume I of the TRANSACTIONS there has been published during the three years of its existence 3424 editorial pages of material of interest to the membership or, an average of about 1141 pages per year. Volume I of the TRANSACTIONS contained in twelve issues 840 pages; Volume 2, twelve issues 1238 pages; Volume 3, nine issues 1000 pages, and the three numbers of Volume 4 so far published contain 446 pages. For convenience of handling and reference it became necessary to issue the TRANSACTIONS in two volumes a year rather than one, as the one volume would contain in the neighborhood of 1500 pages which makes it undesirable for binding purposes as well as for ready reference. Consequently, beginning with the July, 1923 issue, Volume 4 was started, this closes with the December 1923 issue. It is probable that about 1000 pages of editorial matter will be printed and ready at that time for binding in Volume 4. Thereafter each volume will include six numbers of the TRANSACTIONS.

During the same period as covered by Volume 1 and Volume 2 there was published in the 1923 TRANSACTIONS 1446 pages of reading matter or an increase of 17 per cent over that published last year. This increase in volume of printed matter, increased labor and expense in the preparation of the same, but it is believed as most frequently stated that the TRANSACTIONS alone is sufficient to repay an individual for his membership in the society.

Data Sheets

Progress is being made in the preparation of data sheets for the handbook, through the national office.

The board of directors has decided that all data sheets shall be passed by the Standards committee before being sent to the members.

While this work entails a large amount of detail it nevertheless is making satisfactory progress and it is the hope and expectation

of your secretary that within the period of two months after the close of this convention the first sets of data sheets will have been approved by the Standards committee of the American Society for Steel Treating and be ready for the use of the membership.

The Standards committee has already decided that the sheets are to be LeFax size, so binders in several grades are available to the membership at cost. After the first series of data sheets are out, it is then expected that data sheets will be forwarded to those members in good standing at least three or four times a year.

The method for the compilation of the society handbook has been somewhat changed from the plan originally announced, and it is now to be a composite work of all of the members of the American Society for Steel Treating. Each member will receive credit in the handbook for the data sheets he prepares and presents.

The list of data sheets given below has already been suggested and material has been submitted upon the larger portion of the list. However, the submitted material is first forwarded to a number of members of the society who are familiar with the subject under consideration and after their comments and criticisms have been returned, proper notation and revision of the material is made according to the constructive criticisms and suggestions received. The material is then *again* submitted to another group of members interested in the subject. The second revision is then submitted to the Standards committee of the American Society for Steel Treating. After approval by the Standards committee it is to be printed and forwarded for use by the members.

There will be included in the first set of data sheets the report of Subcommittee I of the Standards committee, on "Recommended Practice in the Heat Treatment of Plain Carbon Tool Steel," and "Recommended Practice in the Heat Treatment of 18 per cent Tungsten High Speed Steel," as well as the report of Subcommittee IV, dealing with "Thermoelectric Pyrometers and Instructions for their Use in Heat Treating Steel."

The subjects upon which data sheets are being prepared, in which either the material is at present available, or in preparation follows:

Influence of Nickel
Influence of Vanadium

Influence of Tungsten
Influence of Uranium
Influence of Molybdenum
Influence of Chromium and Manganese
Influence of Silicon
Blue Brittleness
Etching Solutions to Be Used and Structure Revealed by Each
Etching Solutions and Their Preparation
Specific Heat of Air
Iron and Steel Metallurgy in Brief
Standard Shapes and sizes of Firebrick
Phase Rule
Forging Temperatures
Fuel and Energy Loss of Furnace Walls
Equivalent Quantity of Fuel Based on Heat Values
Characteristics of Various Gases
Nitrogen in Steel
X-ray Investigations
Gases in Metals
Deep Acid Etching
Salt Baths
Temperatures Judged by Colors
Fuel Areas for Furnaces
Comparative Costs of Various Fuels on B.t.u. Basis
Specific Heat of Iron and Steel
Melting Points Sodium and Potassium Nitrate
Thermal Conductivity of Insulating and Refractory Material
Temperature Conversion Table
Table for Carburizing and Heat Treatment of Carburized Steel
Iron-Carbon Critical Range Diagram
Temperature Color Charts
Brinell Hardness Numbers
Critical Range Diagram for Iron Carbon Alloys
Volume Weight Tables Carbon and High-Speed Steel
Tempering Table
Ghost Lines
Effect of Size and Mass on Physical Properties
Alpha Beta and Gamma Iron

Use and Care of Pyrometer
Lead Baths
Strength of Steels at High Temperatures
Transfer of Heat
Hardness of Carbon-Manganese Steel
Physical Properties of Alloy Steel
Cutting Tests on High-Speed Steel
Recommended Heat Treatment of Plain Carbon Tool Steel
Recommended Heat Treatment of 18 per cent Tungsten High-Speed Steel
Hardness of 1 per cent Carbon Tool Steel
Physical Properties of Carbon Steel

Special Services

Many of the members of the American Society for Steel Treating have availed themselves of the opportunity to secure reprints of articles as well as translations of papers appearing in foreign and local publications through the national office. While the demand has not reached enormous proportions it is, nevertheless, of sufficient strength to indicate that the membership appreciates quite thoroughly having this service available.

The employment bureau which functions through the National office is still of great benefit to the membership and has been successful during the past year in placing many of the members in contact with desirable openings as well as securing for employers men satisfactory to their needs.

About 250 members availed themselves of the offer of the national office to secure TRANSACTIONS binding for them at the cost of the work, and in that way they have been able to have their volumes bound uniformly each year at a minimum of expense and effort.

The staff of the national office consists of the editor of the TRANSACTIONS, a bookkeeper, two stenographers and a membership file clerk.

Some idea of the work involved may be gathered from the statement that over 100,000 pieces of mail matter leave the office annually not including the copies of the TRANSACTIONS which add a total of 36,000 more pieces. No effort has been made to work short-handed because it is realized that the service of the national

organization is one of the important requisites of the society. We are quite confident that the report of the National Treasurer showing how the activities of the society have been conducted with increasing success from a financial standpoint is gratifying and encouraging. It is interesting further to note that the advertising revenue from the TRANSACTIONS has been increased during the year.

The exposition has made rapid progress and this year is 50 per cent larger than the one at Detroit last year. It is recognized as one of the principal annual events in the iron and steel industry.

The advancement the society has been able to make in the three years of its organization is indeed a point of just pride with the entire membership, and so far exceeds their fondest hopes and expectations that they view with pleasure the fact that the society has so rapidly taken front rank in the industry it represents. This rapid and commendable progress is the result of the united energies, both moral and financial, of all its members. The American Society for Steel Treating will not permit self-satisfaction to be its motto, but will always continue to be the synonym for Advance, Efficiency and Service.

CORROSION IN MINE WATERS, AND RECENT INVESTIGATIONS OF IT BY THE U. S. BUREAU OF MINES*

By Robert J. Anderson and George M. Enos

Abstract

This paper discusses the problem of corrosion in a general way, especially as applied to the corrosion of metals and alloys in acid mine waters. The several theories of corrosion are discussed and it is pointed out that these do not explain the fundamental cause for corrosion.

Total immersion tests have been made on a large number of irons and steels for corrosion in acid mine water, and it has been shown that this corrosion is much different from that occurring in air. The results and photomicrographs of long-time immersion tests which have been made on some 45 metals and alloys are incorporated in this paper.

An accelerated electrolytic corrosion test apparatus is described.

Introduction

DURING the past several years, investigation has been carried on by the U. S. Bureau of Mines on the corrosion of metals and alloys in acid mine waters of coal mines in the western Pennsylvania coal region, and the object of the present paper is to discuss briefly the corrosion problem in a general way, and to direct attention to certain of the results obtained in tests on the corrosion of metals and alloys in acid waters from coal mines. Numerous other investigations on corrosion have been carried out in the past by the bureau, but these need not be taken up here. The work discussed in this paper has been carried out in co-operation with the Carnegie Institute of Technology, Pittsburgh, Pa., under a co-operative arrangement with the coal-mining industry of

*Published by permission of the Director, U. S. Bureau of Mines.

This paper is an abstract of a lecture given before the Pittsburgh
ors, Robert J. Anderson is metallurgistchapter of the society. Of the auth
and George M. Enos is junior metallurgist, both of U. S. Bureau of Mines,
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western Pennsylvania. Samples of metals and alloys for test have been very kindly supplied by industrial firms. The work has been under the general supervision of A. C. Fieldner, superintendent and supervising chemist, Pittsburgh Experiment Station, U. S. Bureau of Mines.

It is well known that the search for alloys that will withstand corrosion influences is one of the most energetically explored fields of physical metallurgy, but so far experimental work has been on an empirical basis solely, and notably good results are quite accidental. In selecting alloys for use as engineering materials of construction in structures where particularly corrosive atmospheres or solutions must be withstood, it is necessary to consider not only the resistance to corrosion of the materials under the specific conditions of employment but also their physical properties, ease of fabrication or casting, and cost. The latter items are often overlooked by those working on the development of corrosion-resisting alloys. The corrosion of alloys in acid mine water is a typical example of the failure of engineering materials under attack by corrosive solutions, and in selecting alloys for use in pumping equipment for mines, one of the most important properties for consideration is the corrodibility of the materials.

Water from coal mines is usually decidedly acid and causes considerable trouble and expense to operators because of its corrosive action on mine equipment. Water from metal mines is also frequently corrosive, e.g., that of the Montana copper mines. Underground waters in coal mines are acid from the presence of free sulphuric acid and sulphates of iron and aluminum, and such waters will readily corrode ordinary ferrous and nonferrous materials.

The object of the recent work of the bureau has been to investigate the corrosion of commercial metals and alloys by acid mine waters, and certain of the work has been published. Thus, W. A. Selvig* and one of writers[14] have investigated the comparative corrosion losses of 45 metals and alloys on immersion in acid mine waters, and the writers [18] have studied the microscopic features of these corroded materials.

*Numbers refer to bibliography appended to this paper.

Most recently, study has been made by the writers and J. R. Adams (research fellow of the Carnegie Institute of Technology) on the fundamentals of corrosion, corrosion theories, and the development of an accelerated test for corrosion. The results of this work will be published later. It may be added that in the selection of alloys for withstanding corrosive conditions it is necessary that the selection be based on reliable and adequate tests, and so far no standard method for corrosion testing has been developed. For examining the relative corrodibility of different metals and alloys in solutions, the most satisfactory test has been the long-time immersion test, but this has the decided disadvantage of consuming considerable time.

The corrosion of metals and alloys in specific corroding media like mineral acids, sea water, fresh waters, salt solutions, atmospheric air, and gases has been studied in detail for many years, but it is only recently that systematic investigation has been undertaken on the corrosion of materials in acid waters from coal mines. At present the corrosion of pump parts (rods, valves, etc.) by acid mine waters in the western Pennsylvania coal region is very serious, and it should be added that rails, rolling stock, tools, and other equipment corrode when exposed to the action of acid waters. The work of the bureau on corrosion in mine waters has been carried out specifically with a view of procuring data that might help in the solution of the difficulties experienced by mine operators. Though no data are available as to the monetary values of the losses incurred through the corrosion of equipment in mines, the total is considerable. Moreover, additional financial loss is occasioned by shutdowns and repairs required, e.g., in the stopping of a pump. Hadfield[15] has recently estimated the annual cost of wastage due to rusting of the world's iron and steel as over $3,500,000,000 and no argument is needed to show that anything which can be done to reduce losses here and there in specific cases is worth while.

Theoretical Aspects of the Corrosion Problem

Any discussion of the corrosion problem would be incomplete without at least brief reference to the present status of the theory. A number of different theories have been

advanced to explain the cause of corrosion inception and the mechanism of corrosion processes, but no one of these is satisfactory to account for the initiation of corrosion or to explain the mechanism of all observed cases of corrosion. There certainly can be no fundamental difference in the mechanism of corrosion inception under any conditions, and one of the objects of recent work in the bureau has been to study the fundamentals of corrosion with a view to determining if there could be one explanation underlying all the phenomena observed.

Corrosion is generally regarded as the result of the tendency which a metal has for forming oxides or salts when in contact with a liquid or gas medium, and of the many theories which have been advanced to explain the mechanism of the phenomenon, the electrolytic, acid, and direct oxidation theories have been supported most strongly. The main theories which have been advanced to account for corrosion include the following: (1) simple oxide (or direct oxidation) theory; (2) acid theory; (3) electrolytic theory; (4) auto-colloidal catalytic theory; (5) hydrogen-peroxide theory; (6) adsorption theory; and (7) biological theory. These are briefly discussed below.

Simple Oxide Theory

The simple oxide, or direct oxidation, theory was the first of the modern corrosion hypotheses. This theory has been supported by a number of workers as being exclusively applicable, and some investigators[11] have recently taken the position that some corrosion processes can be explained on the basis of direct oxidation. The theory assumes that a metal is attacked chemically by oxygen or other gas without previously passing into solution, but this is negated by proponents of the electrolytic and acid theories on the basis that liquid water is necessary for corrosion in addition to oxygen.

Acid Theory

The acid theory assumes that in addition to oxygen and water, some acid must be present before corrosion can take

place, and a weak acid like carbonic acid is sufficient. The process of corrosion is cyclical. This theory has been strongly supported, particularly by Friend,[10] but it may be regarded as an electrolytic theory not necessarily expressed in terms of the ionic hypothesis.

Electrolytic Theory

The electrolytic theory considers corrosion to be electrochemical in nature, and according to this, water being an electrolyte and therefore ionized to a small extent to hydrogen and hydroxyl ions, it is not necessary that an acid be present. When a metal is placed in water, or when a metal is under such conditions that a film of water is upon it, the metal tends to dissolve in the water, i.e., it tends to pass from the atomic (metallic) state to the ionic state. As an atom of metal passes into the water, it assumes a positive charge of electricity, leaving the metal mass from which it departed charged negatively. The tendency for a metal to dissolve thus in an electrolytic, is termed its solution pressure, and the result of this tendency is corrosion. This theory was advanced by Whitney[1] and receives general acceptance at the present time. This theory has been termed electrolytic in contrast with the acid theory, implying that the latter is not electrolytic in nature. Of course, both theories are to be interpreted from the electrochemical point of view.

Auto-Colloidal Catalytic Theory

The auto-colloidal catalytic theory recently advanced by Friend, [7, 10] postulates corrosion as starting with the formation of colloidal ferrous hydroxide; this by contact with air flocculates to hydrated ferric hydroxide, which latter is alternately reduced by contact with iron oxidized by contact with air, thus continuing the corrosion and the production of rust. According to Friend, when iron comes into contact with liquid water in the presence of air or oxygen it slowly oxidizes to ferrous hydroxide; this, however, is produced in the colloidal condition—a state in which it is usual for many substances to be particularly reactive chemically. The ferrous hydroxide hydrosol is then oxidized to a higher iron hydroxide

hydrosol, and the ferric hydroxide hydrosol is produced under suitable conditions. This higher hydrosol is then alternately reduced in contact with iron and oxidized again by atmospheric oxygen, thus catalytically accelerating the oxidation of the iron, and when the sol flocculates or precipitates out it yields rust.

Hydrogen-Peroxide Theory

The presence of hydrogen peroxide in the water in which certain metals are corroded has led to the development of the hydrogen-peroxide theory. It has been demonstrated experimentally by Dunstan and his coworkers[2] that hydrogen peroxide is formed as an intermediate product during the corrosion of a number of metals including copper, lead, and zinc, but not iron. Hence, it is alleged that corrosion in many cases is owing to the formation of hydrogen peroxide and its interaction with the metal. The formation of hydrogen peroxide as a corrosion product in the oxidation of a metal by water and air is simply incidental, and this is not necessarily an accompaniment of the initiation of corrosion.

Adsorption Theory

Saklatwalla[12] has recently discussed the effect of adsorption of gases upon the rate and nature of corrosion, assuming that there is a definite relationship between the adsorption of gas by a metal and the corrosion of that metal by the same gas. The suggestion is offered that the phenomenon of adsorption, whereby a gas is condensed as a film on the surface of a metal or of any other solid body, would have the tendency of imparting to that body, surface activities, depending upon the degree of adsorption. The rate of interaction between the condensed gas of a film and the solid metal depends, among other things, upon the density of the film. If a metal has a high degree of adsorption, the condensation and consequent velocity of interaction would be high, and hence surface oxidation would take place rapidly. It is alleged that high interacting velocity, and consequent nearly instantaneous production of a protective film on the surface of the metal, is the essential factor in producing noncorrodibility. Hence, the higher the adsorption capacity, the higher should

be the noncorrodibility. The sum and substance of this theory is that certain metals are noncorrodible because they produce adsorbed surface gas films of high concentration because they in turn adsorb large amounts of gas.

Biological Theory

Claim is made by some biologists that lowly forms of life enter into the reactions which occur when iron corrodes. It is true that animal and vegetable organisms can materially enhance the corrosion of metals because of the action of their secretions, and the biological aspect of the corrosion problem should not be overlook. However, corrosion takes place readily in the absence of living matter, so that corrosion is not prevented by excluding such matter, and no organisms have so far been discovered which can feed upon metals.

Summary

No one of the theories so far advanced serves to explain the mechanism of corrosion inception and no one explains the mechanism of all the observed cases of corrosion. While the establishment of the theories have helped in the understanding of certain anomalous facts concerning corrosion, this has not given any better comprehension of the fundamental cause. The supporters of most of the theories have usually tried to make out a case for a particular theory so as to show that their theory is exclusively correct. The two foremost theories are the electrolytic and the direct oxidation hypotheses, and the position taken by some investigators (notably Bengough) is that corrosion takes place either by electrolytic or direct oxidation means. The view submitted by Bengough is that corrosion may be either chemical or electrochemical in nature and that all corrosion may be explained by one or the other of these two kinds of reactions. The acid theory is interpretable on the electrochemical basis, while the other theories are either untenable or else may be interpreted on the basis of direct oxidation.

Assuming for the moment then that all corrosion is either chemical or electrochemical in nature, the question has been asked, particularly by Bancroft[8]: Are not chemical and elec-

trochemical reactions one and the same thing? Desch and Whyte[4, 5] suggest that there is no difference between electrolytically stimulated and natural (chemical) corrosion, and this view is shared by the writers. That chemical corrosion and electrochemical corrosion are the same qualitatively, but not necessarily quantitatively, has been demonstrated experimentally by the writers.

It should be emphasized that the various theories of corrosion are really not theories which explain the cause for corrosion, but they are rather theories that serve to explain the mechanism of corrosion processes in terms of the older chemistry*.

Factors Affecting Corrosion Processes

For present purposes, corrosion may be properly regarded as chemical reaction, and many factors influence the process and determine the speed of the reaction. The corrosion of metals and alloys may take place under three different conditions: viz., (1) the corroding medium is a liquid (this may be an electrolyte or a nonelectrolyte; (2) the corroding medium is a gas or vapor; and (3) the corroding medium is alternately liquid and gas. While the cause for corrosion inception and progression is the same irrespective of the metal and the corroding medium, the rate of corrosion and the corrosion products formed would be expected to be radically different for different metals and different media. Moreover, there are a number of factors which affect the process of corrosion (chemical reaction), although the relation of these has not been thoroughly worked out.

One of the most common ways in which metals fail by corrosion is by exposure to reacting solutions (or liquids), and the factors involved in the corrosion of metals and alloys when in solution include the following:

(1) Chemical composition of the metal or alloy.
(2) Physical condition of the metal or alloy.
(3) Chemical composition and concentration of the corroding solution (liquid).

*Since the lecture was presented, the writers have applied the electronic theory of the constitution of the atom to the corrosion problem, and this permits explanation of corrosion inception in terms of modern chemistry.

(4) Velocity of the corroding medium, or the velocity of the metal in the medium.
(5) Temperature of the medium.
(6) Time period of exposure.
(7) Solution pressure of the metal which depends upon (1), (2), and (3).
(8) Electrical conditions of immersion.
(9) Effect of light.

Study of these factors should throw light on many corrosion processes, and it should be emphasized that for testing purposes, at least, it is possible to hold all of the factors constant within limits and examine the effects of variations in them.

The factors above mentioned are merely suggestive*, but indicate that in any corrosion process the effects of variable conditions must be properly accounted for.

The corrosion of any metal or alloy in any medium is an expression of the summation of the effects of all influencing factors, and for particular cases the effects may be positive, negative, zero, or negligible. The effects of the variable factors are shown in a variety of ways; viz., by the formation of salts, oxides, or hydroxides; by the deposition of metals, salts, or oxides; by the formation of coatings from the salts, which retard or accelerate corrosion, or have no effect; by the formation of pits; by passivity; by embrittlement; by selective corrosion; by disintegration; and perhaps by other effects not so common.

One of the chief difficulties in expressing the corrosion of a metal or alloy lies in the fact that a loss-in-weight determination is not necessarily indicative of the amount and character of the disintegration. Accurate loss-in-weight determinations can be made only by determining the exact composition of the adhering scale or coating as well as the weight of metal found in solution or suspension, followed by appropriate calculations. In comparing the relative corrodibility of metals, true corrosion loss-in-weight results should be expressed in terms of the molecular ratios of the metals compared. Thus, the rate of corrosion of one metal may be faster

*In the lecture, these factors were discussed at length, but owing to the confines of space, cannot be taken up here.

than that of another but the actual loss less, because of difference in the atomic weights. The rate of corrosion should properly be expressed in such terms that difference in mol weights, solution pressures, polarization, and other factors will be properly accounted for.

Summary of Recent Investigations by the Bureau of Mines

Turning now to the recent studies which have been made in the Bureau of Mines on the corrosion problem, particularly in the case of mine-water corrosion, the following gives a brief resume of the work carried out during the past three years with the results obtained. Before taking up the results of the work, it is advisable to discuss briefly the nature of acid mine water.

Nature of Acid Water From Coal Mines

As indicated previously, water from coal mines is usually decidedly acid, containing free sulphuric acid, and ferrous, ferric and aluminum sulphates, as well as sulphates of calcium, magnesium, sodium and potassium, together with silica, and usually some chlorides. On standing, dilution, aeration, or warming, insoluble iron compounds tend to precipitate from these waters, principally as hydrous ferric oxides. The occurrence of iron sulphates and free sulphuric acid is due to the action of water and air on the pyrite or marcasite associated with the coal. These sulphides are oxidized to ferrous sulphate, and sulphuric acid, and the reactions may be represented by the equations:

$$2FeS_2+7O_2+2H_2O=FeSO_4+2H_2SO_4$$
$$4FeSO_4+2H_2SO_4+O_2=2Fe_2(SO_4)_3+2H_2O$$

It is well known that the acidity and composition of different waters vary considerably at different times, and a range of composition for some waters collected at various coal mines and analyzed by the Bureau of Mines is as follows: silica, 16 to 64 p.p.m.; ferrous iron, trace to 967; ferric iron, 11 to 915; aluminum, 25 to 148; calcium, 79 to 436; magnesium, 34 to 197; sodium, 21 to 133; chlorine, trace to 25; total sulphate radical, 790 to 6370; and free sulphuric acid, trace to 3662 p.p.m. A typical analysis of filtered water (from the Edna

No. 2 mine of the Hillman Coal & Coke Co., at Wendel, Westmoreland county, Pa.) is as follows: silica, 129 p.p.m.; ferrous iron, 516; ferric iron, 1303; aluminum, 1225; calcium, 307; magnesium, 122; potassium, 332; sodium, 512; chlorine, 37; and sulphate, 11,750 p.p.m. The suspended matter (on unfiltered water) in this water dried at 105 degrees Cent. is 19 p.p.m.

It may be added that in connection with the corrosion work, study has been made by Selving and Ratliff[13] of the nature of acid water from coal mines and of methods for analysis. It was found that titration of acid mine water for free sulphuric acid with standard alkali solutions gave too high results, because of hydrolysis of sulphates of iron and aluminum. More nearly correct results were secured by reducing the ferric sulphate present to ferrous sulphate, prior to titration, and this reduction was effected by the addition of potassium-iodide solution to the mine water.

Mine Water Corrosion Tests of Iron and Steel

In 1920-1921, total immersion tests were carried out by W. A. Selvig, assistant chemist of the bureau, for committee A-5 of the American Society for Testing Materials, on the corrosion of a large number of irons and steels of varying composition in acid mine water.[9] The test samples were 2 by 6 inches in size and of 16 and 22-gage. The tests were made by immersing the specimens in flowing acid mine water at the Calumet coal mine of the H. C. Frick Coke Co., Calumet, Pa. The samples were considered to have failed after standing in the water if they had been corroded through or eaten away at the edge for a distance of ¼ inch. After failure, the samples were cleaned, weighed, and the corrosion loss calculated. Photographs of the corroded samples were made. The corrosive action of the acid mine water on all the steels and irons was severe, and the tests clearly showed that all ordinary grades of iron and steel are corroded rapidly by acid waters from coal mines and that there was no great difference in the rates of corrosion among the commercial varieties of these materials.

In these tests, the acidity due to free sulphuric acid was about 700 p.p.m. on the average, and the total acidity (that due

to free sulphuric acid plus sulphates of iron and aluminum) was about 1700 p.p.m. on the average. In all, 49 different irons and steels were tested, and comparison was made between the results obtained in mine water and those obtained on corrosion in atmospheric air. The results were quite different.

Mine Water Corrosion Tests of Forty-Five Metals and Alloys

In 1921-1922, comparative corrosion test was made of 45 metals and alloys in acid mine waters for the purpose of securing data relative to materials for use in pumping equipment. This investigation was carried out as part of a co-operative agreement between the Bureau of Mines and the Carnegie Institute of Technology. The materials tested included a variety of ferrous and nonferrous metals and alloys in the rolled and cast condition, and the waters used were from three coal mines: viz., the Montour No. 1 mine of the Pittsburgh Coal Co., at Southview, Washington county, Pa.; the Edna No. 2 mine of the Hillman Coal & Coke Co., at Wendel, Westmoreland county, Pa.; and the Calumet mine of the H. C. Frick Coke Co. at Calumet, Westmoreland county, Pa. The different materials tested were in the form of rectangular pieces 2 by 6 inches in size, the rolled materials being about 16 gage thick (0.051 inch), and the cast materials approximately ¼ inch thick. The pieces were placed in racks in test boxes especially designed for the work, so as to permit total immersion of the samples in flowing water. The construction of the test boxes and racks, which were made of wood, is shown in Fig. 1. The general arrangement of two test boxes on the surface at the Calumet mine is shown in Fig. 2. At the Montour No. 1 mine, sufficient head of water could not be obtained to cause a continuous flow of water through the boxes, and the racks holding the samples were placed in the mine sump. At the other two mines, the velocity of water flow around the samples was regulated to 1.8 inches per minute. The test covered a period of 119 days at the Montour No. 1 mine, 135 days at the Edna No. 2 mine, and 98 days at the Calumet mine. The complete results of the investigation have been reported by Selvig and one of the writers.[14]

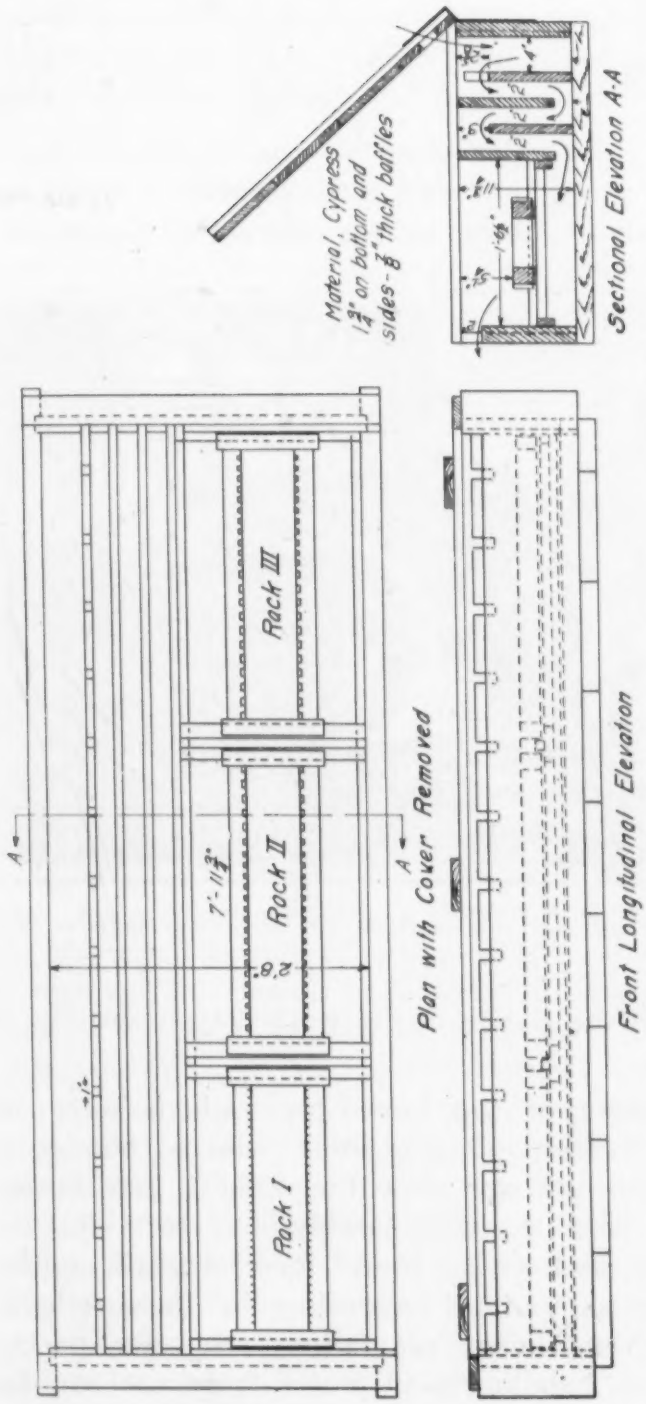

Fig. 1—Construction of Wooden Test Boxes, for Total Immersion in Acid Mine Water.

Roughly, the average acidity of the waters was as follows:

Mine	Free Acidity p.p.m.	Total Acidity p.p.m.
Montour No. 1	1430	11,360
Edna No. 2	2160	14,160
Calumet	430	2,950

Loss-in-weight data were secured for the metals and alloys after exposure to the corroding action of the mine

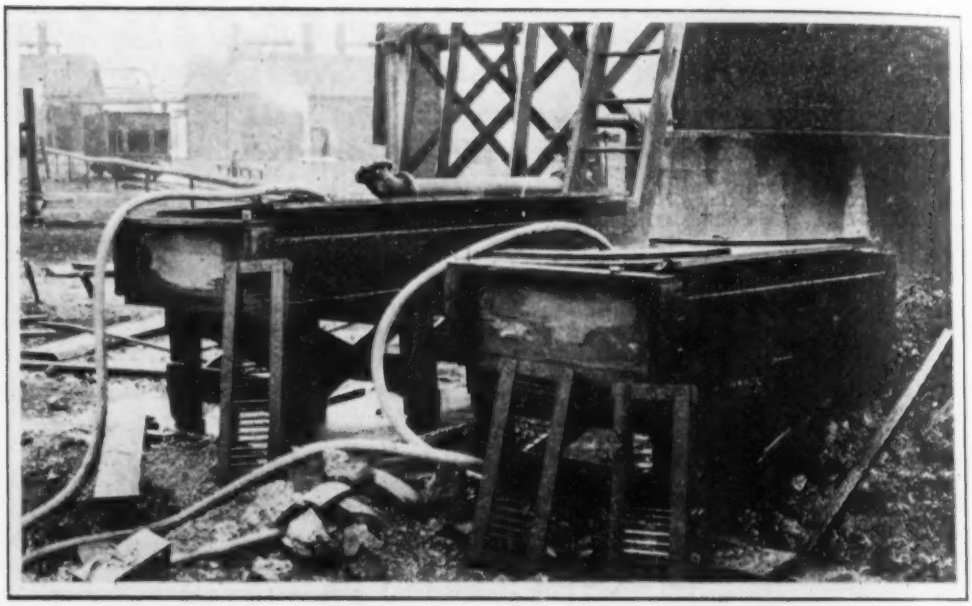

Fig. 2—Arrangement of Test Boxes for Mine Water Corrosion Tests at Calumet Mine.

waters, and the results of the work may be briefly summarized as follows:

All alloys of the brass type which were tested were corroded severely by the mine waters; the corrosion was uniform (no pitting), and the weight loss large. Bronzes were also corroded considerably, but to a less extent than the brasses, and within limits increasing tin appeared to decrease the amount of corrosion in these alloys. At the present time, bronzes are largely used for parts in pumps designed for handling acid water from coal mines. Copper-nickel alloys were corroded in about the same amount as the brasses; the loss in weight was large, and the corrosion

was uniform. Nickel silvers of various compositions (copper-nickel-zinc alloys) were badly corroded—the attack in most instances being uniform. Aluminum alloys showed a marked tendency to pronounced pitting; the loss in weight was comparatively small, but the pitting effect precludes the possibility of their use in acid mine water.

The materials which showed practically no corrosion in the mine waters included a high-chromium steel, two chromium-nickel-silicon steels, a high-silicon cast iron, and a nickel-chromium-iron alloy. All these alloys contained large amounts of chromium with the exception of the high-silicon cast iron. Commercial nickel corroded very little in the Edna No. 2 mine water but corroded considerably in the waters from the other two mines.

Taking the materials by groups, the relative corrosion losses may be taken roughly as follows, in the Edna No. 2 mine water: Brasses, 6 to 7 mg. per sq. cm. per day; bronzes, 1 to 3 mg.; cupro-nickel alloys, 5 to 7 mg.; nickel-silver alloys, 5 to 7 mg.; aluminum alloys, 2 mg.; high-silicon cast iron, 0.006 to 0.6 mg.; high-chromium steel, 0.0004 mg.; chromium-nickel-silicon alloys, 0.0002 mg.; and nickel-chromium-iron alloy, 0.002 mg. per sq. cm. per day.

A large number of the samples became covered with coatings during the course of the tests. Some of the materials had rather thick, soft, fine-grained coatings which adhered fairly tightly, but could be readily removed with a fiber brush and water. Others had loosely adhering coatings, and these could be readily removed by rinsing in water and rubbing with the hand. Some of the samples had hard, closely adhering coatings. It was shown that the coating formed may accelerate or retard corrosive action or have no appreciable effect. It should be pointed out that the physical condition of the surface of materials is a factor affecting the nature of the coating formed, and this is illustrated nicely by the photomicrographs of Figs. 3 and 4. Fig. 3 shows the coating on a copper-chromium-iron-nickel alloy, formed on an as-cast sample, while Fig. 4 shows the coating formed on the same alloy on a machined sample. The coating in the second case is much thicker and coarser than in the first case.

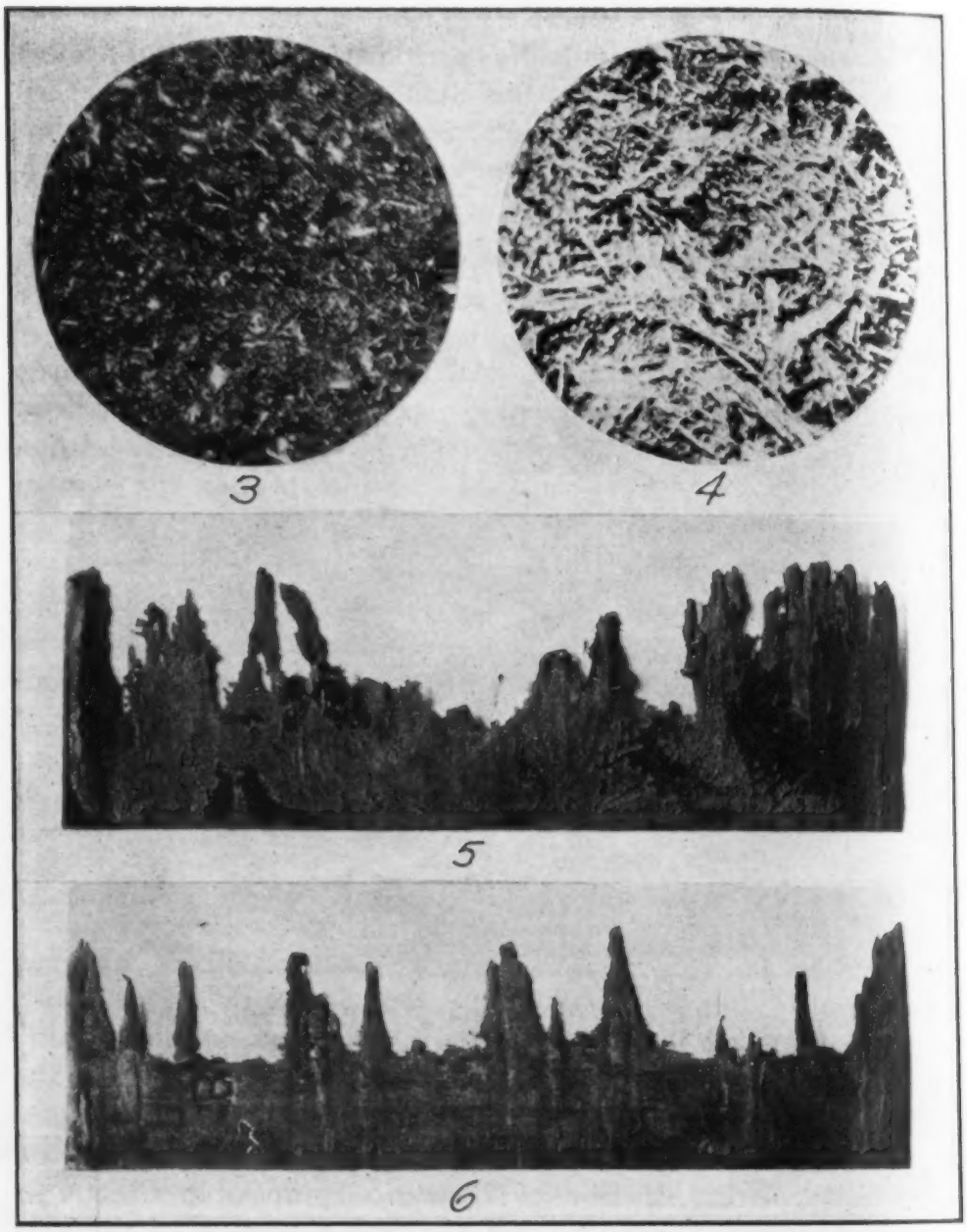

Fig. 3—Photomicrograph Showing Coating on an As-cast Sample on Exposure to Acid Mine Water. x25. Nominal Composition, 42:12:9:35, Cu-Cr-Fe-Ni (plus Si). Fig. 4—Same as Fig. 3, but on a Machined Sample, x25. Fig. 5—Rolled, High Brass. Nominal Composition, Copper 66.6%, Zinc 33.4%. Coating Easily Removable. Considerable Uniform Corrosion. Immersed 65 days—Loss in Weight, 7.38 mg. per square cm. per day. Fig. 6—Rolled, Cupro-Nickel. Nominal Composition, Copper 85%, Nickel 15%. Coating Easily Removable. Considerable Uniform Corrosion. Immersed 65 Days. Loss in Weight, 7.47 mg. per square cm. per day.

In passing, it is of interest to refer to the appearance of certain of the samples after corrosion by the acid waters,

and Figs. 5 to 11 inclusive may be noted in this connection.* Fig. 5 shows the appearance of a corroded sample of rolled, high brass, Fig. 6 a cupro-nickel alloy, Fig. 7 a cast bronze, Fig. 8 a cast copper-lead alloy, Fig. 9 a rolled aluminum-manganese alloy, Fig. 10 a rolled chromium-nickel-silicon steel, and Fig 11 a rolled high-chromium steel. The captions on the figures make the illustrations self-explanatory. All these samples were exposed to water from Edna No. 2 mine.

The investigation reviewed briefly above yielded comparative loss-in-weight data for a series of commercial metals and alloys when exposed to the action of acid mine waters, indicating that of 45 materials tested, only five were suitable from the point of view of corrosion resistance. These five materials are suitable for use in acid mine water from the point of view of resistance to corrosion, but they are not necessarily suitable when economic considerations, ease of fabrication, and physical properties are taken into account. A summary of this investigation has been given in another place by one of the writers.[16]

Microscopy of Corroded Materials

In 1922-1923, microscopic study was made of the corroded metals and alloys from the above described investigation, and the results have been published by the writers[18]. In the long-time immersion tests, a number of phenomena were observed in the behavior of the materials tested, particularly in connection with their rates of corrosion, the formation of surface coatings, and the relation of chemical composition to corrosion rates and coating formation. In the microscopic study, technique was first developed for preparing micro-sections of the corroded samples, and in all 52 samples were examined. The conclusions drawn from the work may be summarized as follows:

In brasses, grain size seems to have little effect upon the rate or nature of the corrosion. In alloy systems where two or more phases are present, there is usually, although not necessarily, one phase that is more resistant to corrosion than the other phases. This gives rise to selective corrosion. In bronzes, the delta constituent is the more resistant phase; in alpha-beta

*In the lecture, a large number of slides illustrating the appearance of corroded samples were shown, but only a few typical photographs can be given here.

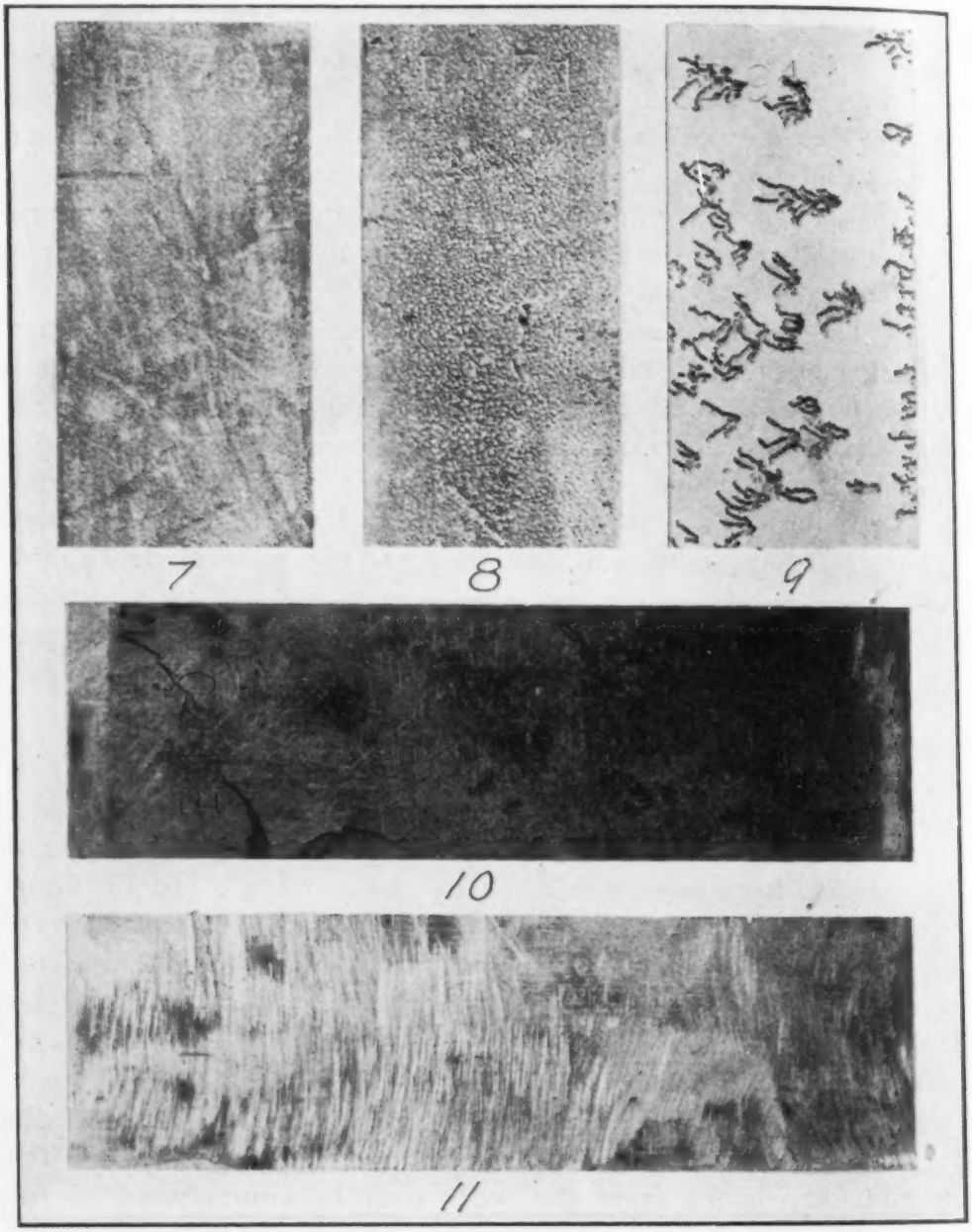

Fig. 7—Cast Bronze. Nominal Composition—Copper 90%, Tin 10%. Coating Partly Removable. Irregular Corrosion. Immersed 135 Days. Loss in Weight—1.90 mg. per square cm. per day. Fig. 8—Cast, Copper-Lead Alloy. Nominal Composition—Copper 50%, Lead 50%. Coating Easily Removable. Uniform Corrosion with some Irregular Pitting. Immersed 121 Days. Loss in Weight—3.94 mg. per square cm. per day. Fig. 9—Rolled, Aluminum-Manganese Alloy. Nominal Composition—Aluminum 98.5%, Manganese 1.5%. No Coating. Irregular Pitting. Immersed 7 Days. Loss in Weight—2.64 mg. per square cm. per day. Fig. 10—Rolled, Chromium-Nickel-Silicon Alloy. Nominal Composition—60:24:13:3, Fe:Ni:Cr:Si (with low carbon). No Coating. No Visible Corrosion. Immersed 135 Days. Loss in Weight—0.00045 mg. per square cm. per day. Fig. 11—Rolled, High Chromium Steel. Nominal Composition—Iron 70%, Chromium 30%, Carbon 0.36%. No Coating. No Visible Corrosion. Immersed 135 Days. Loss in Weight—0.00045 mg. per square cm. per day.

brass, the alpha is more resistant. The other materials examined were of such types that selective corrosion did not occur, or if it did, the constituent first corroded could not be determined. The aluminum alloys pitted so badly that selective corrosion could not be identified as such. Some alloys, which after corrosion and subsequent cleaning, appear to be free from adhering coating or precipitate, have a hard and probably quite impervious coating acting as a protection; this is particularly true of the bronzes. In general, corrosion attack does not follow grain boundaries but proceeds through the less resistant material if two or more phases be present. The more resistant material is probably removed, as such, after the less resistant material has been corroded and washed away. Microscopic examination of the corrosion resisting high-silicon iron, high-chromium steel, chromium-nickel-silicon steels, and nickel-chromium-iron alloy reveals no visible protective coating or film. The resistance of these alloys to corrosion can probably be traced to their chemical composition. It should be added that iron silicide and the double carbide of iron and chromium are very insoluble in acids.

The microstructural aspects of some of the typical corroded samples may be found of interest, and Figs. 12 to 19 inclusive may be examined in this connection.* Fig. 12 shows the corroded edge of a sample of admiralty brass; the ridge lies between shallow elongated pits. Fig. 13 shows a nodule of redeposited copper on the surface of a low brass. Fig. 14 is a macrograph of the cross section of a manganese brass, showing the very even redeposition of copper after corrosion; the dark outer edges contain about 90 per cent copper, and the light center area is the uncorroded brass. Fig. 15 shows the grain boundaries, retained from the original structure, in the redeposited copper of Fig. 14. In Fig. 16 is shown the corroded edge of a leaded bronze, with the delta constituent standing up at the edge. Fig. 17 is a macrograph of substantially pure aluminum, showing the deep pits formed. Fig. 18 shows the pitting in a copper-lead alloy, resulting from the selective corrosion of the copper. Fig. 19 shows cracking in a high lead alloy, which actually gained in weight on exposure to the

*In the lecture, a large number of slides showing the microstructure of corroded samples were presented, but only a few typical micrographs can be reproduced here.

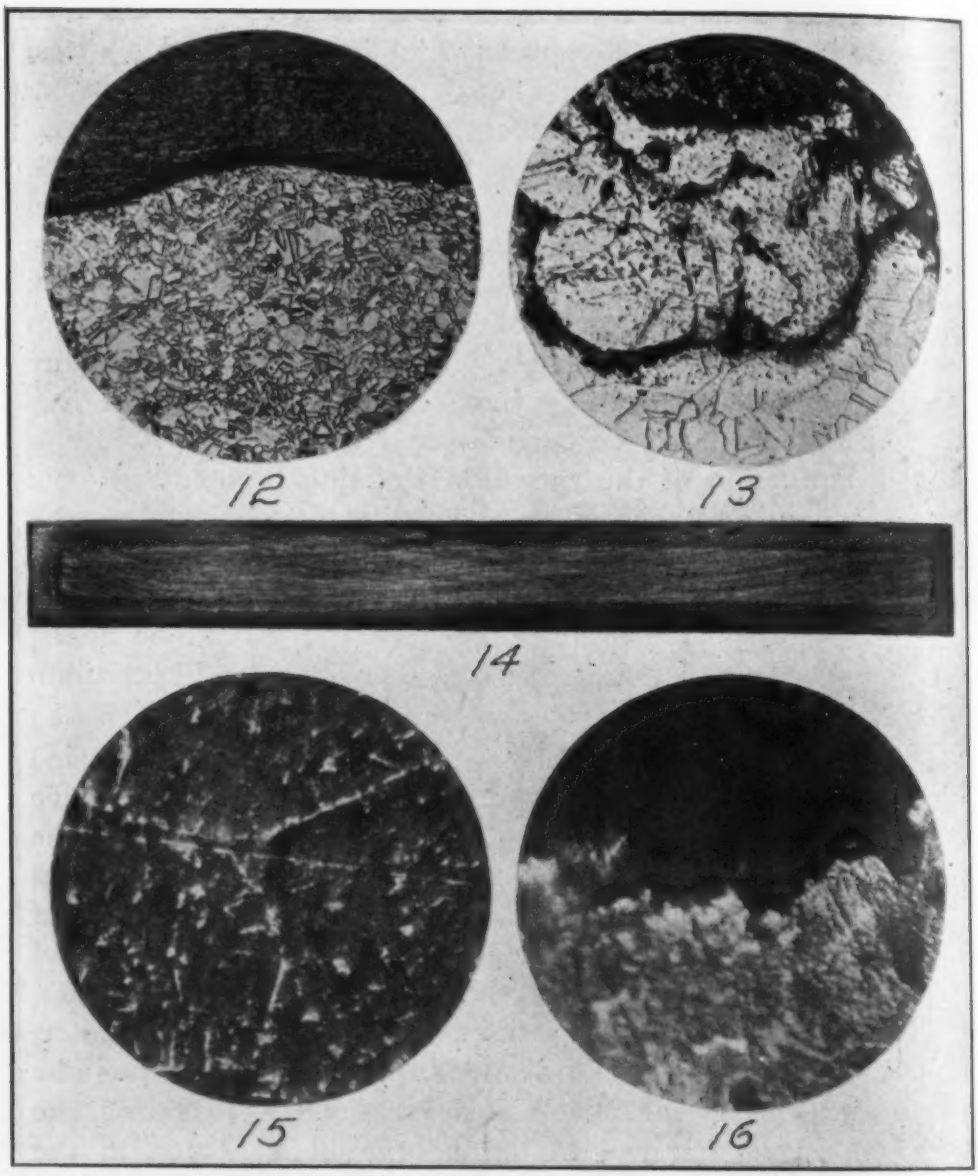

Fig. 12—Edge of Admiralty Brass. Nominal Composition, Copper 70%, Zinc 29%, Tin 1%. Grain Size, 0.035 mm. Immersed 35 Days. Etched in Ammonia and Hydrogen Peroxide. x100. Fig. 13—Low Brass. Nominal Composition—Copper 80%, Zinc 20%. Immersed 119 Days. Photomicrograph Shows Nodule of Re-deposited Copper on Surface. Etched with Ammonia and Hydrogen Peroxide. x100. Fig. 14—Manganese Brass. Nominal Composition—Copper 68%, Zinc 28%, Iron 2%, Manganese 2%, Cross-section of Test Piece Showing Redeposition of Copper. Immersed 72 Days. Oblique Illumination x2. Fig. 15—Showing Microstructure of the Outer Edge of Fig. 14. Etched with Ammonia, Hydrogen Peroxide and Acidulated Ferric Chloride. x300. Fig. 16—Cast, Lead Bronze. Nominal Composition—Copper 75%, Tin 10%, Lead 15%. Immersed 135 Days. Etched in Acidulated Ferric Chloride. x300.

mine water. The samples represented by these figures were all exposed to the Edna No. 2 mine water with the exception of Fig. 13, where the sample was exposed to the Montour No. 1 mine water. The captions on these several figures make the

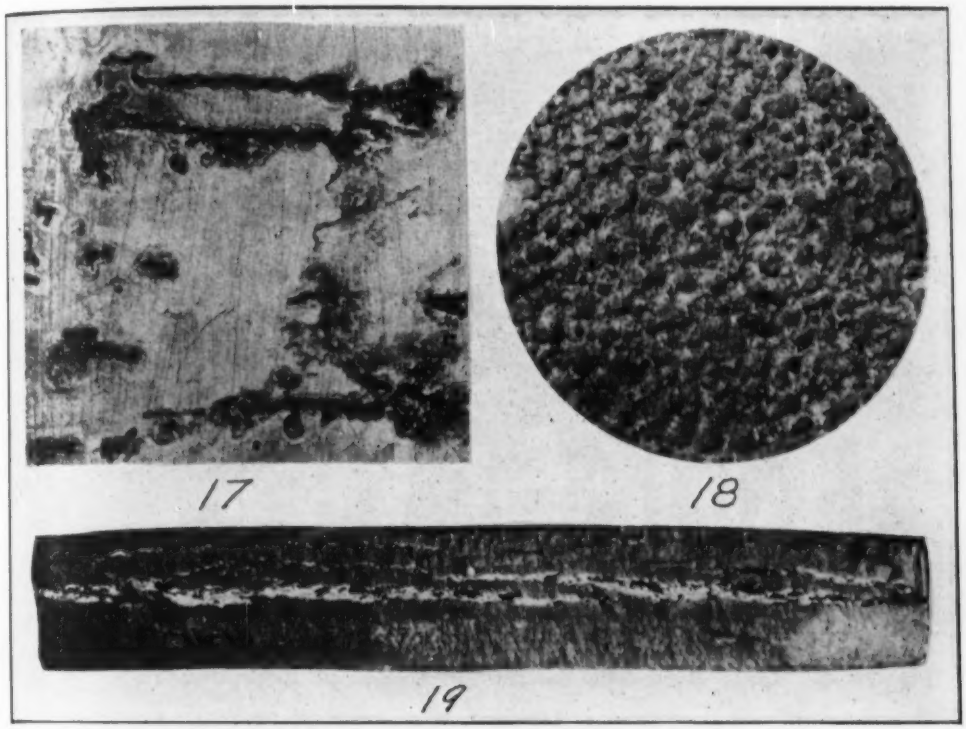

Fig. 17—Substantially Pure Aluminum. Immersed for 21 Days. Unetched. x2. Fig. 18—Cast, Copper-Lead Alloy. Nominal Composition—Copper, 50%, Lead 50%. Immersed 121 Days. Unetched, Oblique Illumination. x5. Fig. 19—Cast, High Lead Alloy. Lead 96% plus Alkaline-Earth Metals. Immersed 72 Days. Unetched, Oblique Illumination. Cross-section. x2.

illustrations self-explanatory. Since the alloys which were very resistant to corrosion were not visibly attacked, photomicrographs of these need not be included.

This investigation demonstrated the desirability of microscopic examination in the study of corrosion, and the writers feel that considerable light can be thrown on corrosion processes by microscopic study of corroded samples.

Fundamentals of Corrosion

In 1922-1923, study was made by the writers and J. R. Adams of the fundamentals of corrosion and the factors affecting corrosion processes. In this connection, the various

theories of corrosion were examined and it was shown that these do not serve to explain corrosion inception although they can be applied to explain different corrosion processes in terms of the older chemistry*.

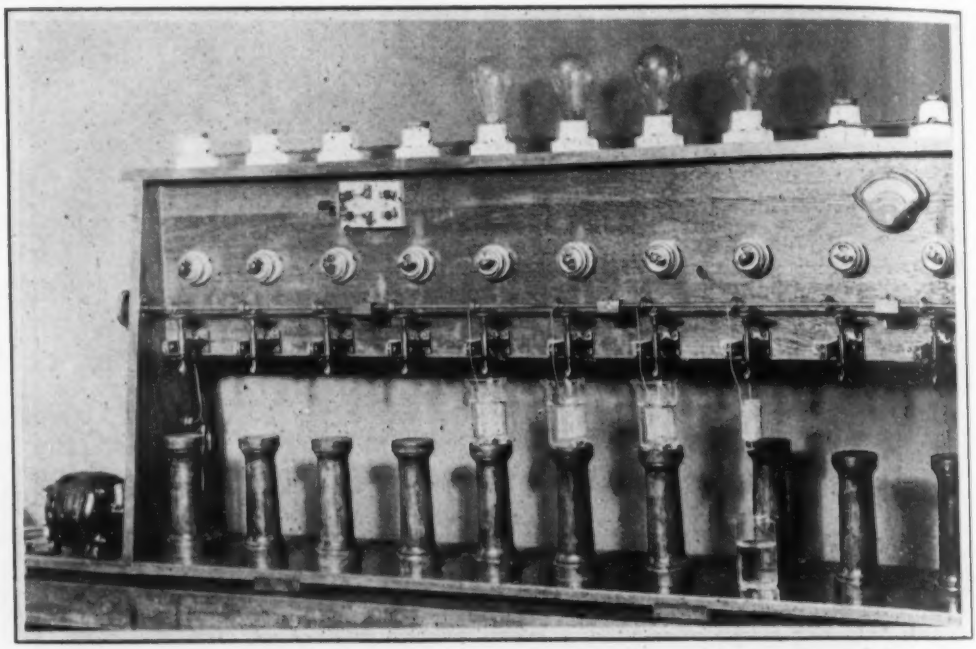

Fig. 20—Set-Up of Electrolytic Cabinet for Accelerated Electrolytic Tests.

Accelerated Corrosion Testing

In 1922-1923, investigation was made by the writers and J. R. Adams of the possibility of developing an accelerated test for corrosion. The attempt was first made to develop an accelerated chemical test, so-called, in which test samples were corroded in a liquid medium and acceleration given by introducing oxygen or air into the medium. It was found that the acceleration by this method over the ordinary long-time immersion test was very slight, and this method was abandoned. The attempt was next made to develop an accelerated electrolytic test, and this was entirely successful. A number of experiments were made on the electrolytic corrosion of bronzes in order to repeat the work reported by previous investigators, and duplicate results were readily obtainable. In

*Since this lecture was given, the writers have applied the electronic theory of the constitution of the atom to the corrosion problem, and this permits explanation of corrosion inception in terms of modern chemistry.

carrying out this work, cylindrical samples of copper—tin alloys were made anode in several solutions including sodium chloride, sodium sulphate, sodium nitrate, and ammonium oxalate plus oxalic acid. The test pieces were rotated, and the current density was 0.179 amperes per square decimeter, of exposed surface area. Runs were also made where the effects of several factors, including variation in current density, time of exposure, and shape of test piece, were examined.

Finding that the results of other investigators could be readily duplicated, accelerated electrolytic corrosion tests were made on 42 of the metals and alloys corroded in long-time immersion test in the previous investigation by W. A. Selvig and one of the writers[14], and the results of both tests were correlated. Mine waters from the Montour No. 1, the Edna No. 2, and the Calumet mines were used as the electrolytes. Fig. 20 shows the apparatus employed for the tests; this is simply an ordinary electrolytic apparatus, with rotating anode spindle connections, as used for the analysis of metals and alloys but built especially for corrosion testing. It was shown as a result of these tests that the corrosion of metals and alloys can be greatly accelerated by the electrolytic method*.

Summary

This paper has discussed the corrosion problem briefly and in a general way, especially as applied to corrosion of metals and alloys in acid mine waters. The following is a brief summary:

1. The U. S. Bureau of Mines has been carrying on an investigation of corrosion for three years in co-operation with the Carnegie Institute of Technology, dealing particularly with the corrosion of metals and alloys in acid mine waters.

2. Considerable trouble is experienced by mine operators in the western Pennsylvania coal region because of the corrosion of equipment, notably pumps, by acid mine waters.

3. The several theories of corrosion are discussed briefly, and it is pointed out that these do not explain the fundamental cause for corrosion.

4. Total immersion tests have been made on a large

*Since the lecture was presented, this work has been developed and elaborated, and the complete results will be published later.

number of irons and steels for corrosion in acid mine water, and it has been shown that the corrosion is much different from that in air.

5. Long-time immersion tests have been made on 45 metals and alloys in three acid mine waters for corrosion, and the comparative corrodibility determined. The data obtained are of value in selecting alloys for mine pumps.

6. Study has been made of the microstructural aspects of these 45 metals and alloys after corrosion.

7. Study has been made of the fundamentals of corrosion.

8. An accelerated electrolytic test has been developed for determining the corrodibility of materials in electrolytes.

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HIGH-POWER PHOTOMICROGRAPHY OF METALLURGICAL SPECIMENS

By Francis F. Lucas

Abstract

The subject of high-power photomicrography of opaque metallurgical specimens is discussed in this paper. The author points out that it is more or less an accepted idea that photomicrographs in excess of 1500 *diameters magnification are of little or no value. Exception is taken to this point of view and the author shows that remarkable definition may be attained at high magnifications. Representative photomicrographs, principally of academic interest, are reproduced to show the attainment of definition, resolution, and penetration at high powers.*

The author discusses briefly and somewhat generally the possibility of high-power metallography, the best type of equipment to use and the need for great care in the preparation of the specimen.

The halftone reproductions inevitably show less detail and brilliancy than the original photomicrographs.

PHOTOMICROGRAPHY of metallurgical specimens is generally confined to magnifications ranging from a few diameters to about 1500. Very few pictures of metal structures have been published at magnifications exceeding 1000 diameters, and apparently many people believe that magnifications in excess of 1500 diameters are of little or no value.

Usually no one photomicrograph will serve for all purposes. Low-power work may be likened to an observer at a lookout station on a mountain top. He sees the country for miles around and by his elevated viewpoint he obtains perspective. Let him observe the ground upon which he stands and he loses the broad general view, but is able to grasp small details wholly unseen in the distant view—virtually a case of high-power work.

A paper by Francis F. Lucas, the photomicrography of which was performed in the research laboratories of the American Telephone & Telegraph Co. and the Western Electric Co., Inc., New York City.

That most photomicrographs are taken at low or medium powers is due, no doubt, to the fact that the equipments ordinarily purchased are not suited to high-power work and consequently development in proficiency has been confined to the field of low or medium power work. To get satisfactory results at high-powers and to get these results consistently, precision equipment is indispensable. The apparatus must be substantially constructed and made for precision work. A compromise outfit which may be adapted to the requirements of both transparent and opaque specimens is only courting trouble because rigidity must necessarily be sacrificed to some extent in order to provide means for adjusting the stand to suit the different classes of work.

At the present time the limitations of high-power metallography do not appear to be with the precision equipment now available but rather with the technique of preparing metallurgical specimens for examination at high powers. It is quite desirable to know the limitations of the apparatus, but it is of considerably more importance to know how best to use the finest equipment to its utmost, because increase in knowledge and better tools go hand in hand. So far as metallurgical work is concerned, it seems to be true that the quality of the best objectives surpasses by far the ability to use them to best advantage.

The Arc as a Light Source

Much has been written on the subject of illuminants for photomicrography, and many statements may be found derogatory to arc lamps, but as a real source of light, a smoothly operating automatic arc lamp equipped with suitable carbons is capable of yielding results of the highest order. Most writers complain of a sputtering arc or irregular feeding of the carbons, but these troubles are readily overcome. Direct current is necessary for successful operation and the carbons should be of small diameters so that the ultimate result will approach closely a point source of illumination. Most automatic arc lamps of this sort have been designed for a certain current, usually about five amperes, and unless the current rating is closely adhered to in practice, the operation is apt to be irregular. Probably the most important part of the illuminant from an operating standpoint is the grade of carbons used. What is needed for high-power work is a point source of light (or approximately so) of great brilliancy, capable

PLATE I
Magnification 1690 X

SUBJECT:	Crystal Grain Orientation in Wrought Iron.
ETCH:	5 per cent Solution of Picric Acid in Alcohol and re-etched with ammonium persulphate, 2 grams to 10 cubic centimeters of water.
OBJECTIVE:	Zeiss 2 millimeter Apochromat.
N. A.	1.4.
OCULAR:	Zeiss Compensating K-18, 20 X.
FILTER:	Wratten "B" 4600 to 5100 A.U.
PLATE:	Wratten "M."
EXPOSURE:	3 minutes.

of being smoothly and uniformly controlled so that the luminous end of the positive carbon will not fluctuate backward and forward within wide limits. As a matter of convenience the carbon adjustment for the initial setting should be such that replacement of the carbons will not consume much time.

Optical Parts — *The Objective*

A great deal may be said about the optical parts, but the objective is the most important part of the whole outfit. No one objective will suffice, and therefore, it is highly desirable to have a whole battery available so that the objective may be selected to suit the requirements of the work. Objectives are divided into four general classes: first, achromatic; second, semiapochromatic;

PLATE II
Magnification 1690 X

SUBJECT:	The Cubic Crystallization of Iron.
ETCH:	5 per cent Solution of Picric Acid in Alcohol and re-etched with ammonium persulphate, 2 grams to 10 cubic centimeters water.
OBJECTIVE:	Zeiss 2 millimeter Apochromat.
N. A.	1.4.
OCULAR:	Zeiss Compensating K-12, 15 X.
FILTER:	Wratten "B" 4600 to 6000 A.U.
PLATE:	Wratten "M."
EXPOSURE:	1½ minutes.

third, apochromatic, and fourth, those for use with ultra-violet light. Of the first three the difference is primarily one of correction for chromatic and spherical aberrations. The apochromats being the most highly corrected are the ones best suited to high-power work.

It is the objective which produces the image; the eyepiece and bellows extension which add magnification. If the objective fails to resolve detail, the final result will be wanting. Obviously, if we are interested in high-power work we are interested in resolving very fine detail; otherwise there would be no object in attempting high magnifications. The resolving power of an objective depends, primarily, upon two things: the numerical aperture of

the objective and the wave-length of the light used. The brightness of the image also varies directly as the square of the numerical aperture. As the numerical aperture increases the flatness of the field and the depth of penetration decrease but usually when high resolution is desired flatness of the field and penetration are not of great concern. For high-power work a Zeiss 2 millimeter apochromatic objective of 1.4 numerical aperture leaves very little to be desired and when used under favorable conditions, these objectives are capable of yielding remarkable depth of penetration at high-powers.

By controlling the color of the light used in photomicrography it is possible to obtain contrast and to improve definition,

PLATE III
Magnification 2450

SUBJECT:	The Cubic Crystallization of Iron.
ETCH:	5 per cent solution Picric Acid in Alcohol and re-etched with ammonium persulphate, 2 grams to 10 cubic centimeters water.
OBJECTIVE:	Zeiss 2 millimeter Apochromat.
N. A.	1.4.
OCULAR:	Zeiss Compensating K-12, 15 X.
FILTER:	Wratten "B" 4600 to 6000 A.U.
PLATE:	Wratten "M."
EXPOSURE:	1 minute.

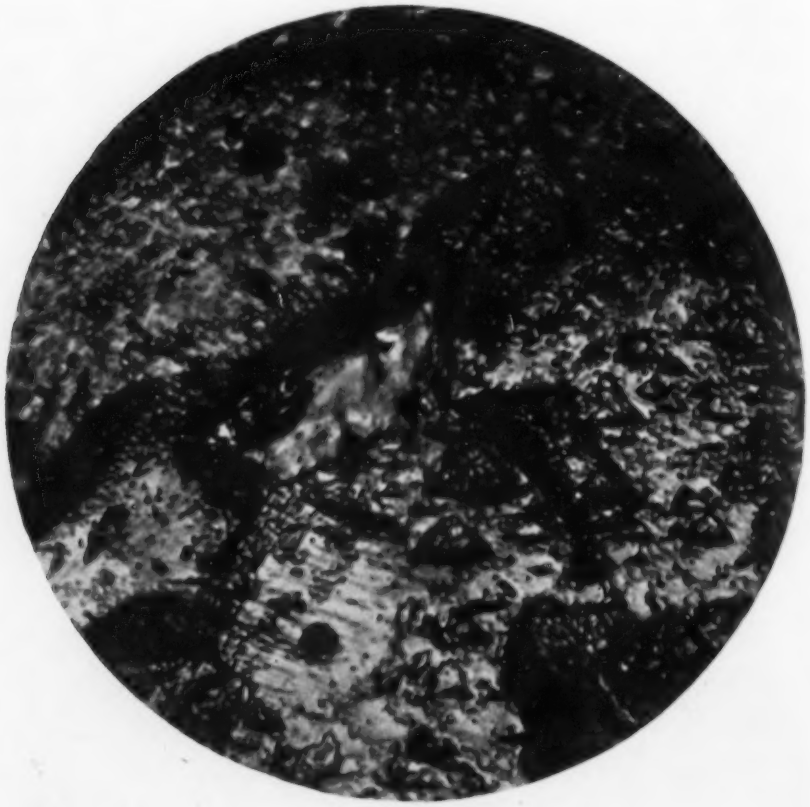

PLATE IV
Magnification 1050 X

SUBJECT: Nickel-iron Alloy.
ETCH: Twenty minutes in a solution consisting of 10 cubic centimeters Nitric Acid, 7.5 cubic centimeters Glacial Acetic Acid and 7.5 cubic centimeters Acetone.
OBJECTIVE: Bausch & Lomb 4 millimeter Achromat.
N. A. 0.65.
OCULAR: Zeiss 20 X.
FILTER: Wratten "E" 5600 A. U. to Red End to Secure Contrast.
PLATE: Wratten "M."
EXPOSURE: 3½ seconds.

This photomicrograph illustrates a nickel-iron alloy at what is usually considered high magnification. Very small triangular shaped pits are shown developed but the magnification is not sufficient to reveal the structure clearly. The following two plates show this crystal structure well developed.

but of greater importance in high-power work is the fact that the resolving power may be increased by decreasing the wave-length of the light used. The relation is expressed as follows:

$$\text{Number of lines per inch resolved} = \frac{2\ \text{N. A.}}{\text{Wave-Length}}$$

Assuming that a Wratten "F" ray-filter is used whose transmission band is from 6100 angstrom units to the red end of the spectrum then an objective of 1.4 numerical aperture should re-

solve about 109,000 lines per inch. If a "C" ray-filter is used whose spectral transmission is from 4000 angstrom units to 5100 angstrom units the same objective should resolve about 158,000 lines per inch. That is, by using the shorter wave-length light it is possible to effect a theoretical improvement of about 45 per cent in the resolution. In practice there is some departure from these theoretical values because of the complications entering into the problem.

If ultraviolet light were used, the resolution would be

PLATE V
Magnification 2300 X

SUBJECT: A Nickel-iron Alloy.
ETCH: Thirty minutes in a solution consisting of 10 cubic centimeters Nitric Acid, 7.5 cubic centimeters Glacial Acetic Acid and 7.5 cubic centimeters Acetone.
OBJECTIVE: Spencer 1.8 millimeter Achromat.
N. A. 1.25.
OCULAR: Zeiss 20 X.
FILTER: Wratten "E" 5600 A. U. to Red End to Secure Contrast.
PLATE: Wratten "M."
EXPOSURE: 15 seconds.

A development of crystal structure from the specimen shown in Plate IV, the bject of which was to show the crystal form. A further development at higher agnification is shown in Plate VI.

greater than when using light whose wave-length lies within the visible spectrum. Since glass is opaque to ultraviolet light, lenses of another material must be used. Monochromatic quartz objectives are available for this purpose.

Preparation of Specimens an Important Factor

When considering the problem of high-power work with metallurgical specimens it is necessary to keep in mind that the surface to be examined must be prepared with the greatest of care, as it is probable that many failures attributed to the optical parts are in reality due to the faulty preparation of the specimen. This has been found to be true in the Bell System laboratories where actual experimental investigations have been carried out and a rather elaborate technique of polishing developed to meet the requirements. It is conceivable that a polish suitable for low or medium-power work would appear rough at 6000 diameters. It has been found that the more perfect the polish the better will be the definition. Further experimental investigations developed the fact that contrary to the usually expressed statement, a light etch does not necessarily give the best results at high powers. If a specimen is to photograph well and yield sharp definition, a contrasting etch is absolutely essential. To obtain the desired result, the etching reagent must be adjusted to the conditions and applied gradually, several applications being preferable to a single one. Examination of the specimen after the first application should show the structure delicately revealed but lacking in contrast. Perhaps the result may best be described by saying that it is "flat," a term well understood in photography. Such structures do not photograph well, but if the pattern is further developed by repeated applications, a state will be reached when the pattern stands out in great contrast and is sharply defined. When this stage is reached the specimen is ready to be photographed and the results are striking, both visually and photographically.

It is recognized that metallurgical specimens tarnish readily and even for low-power work are found unsatisfactory several days after etching and often in less time. This tarnishing effect appears to be cumulative. The writer has found that for high-power work the contrast above described becomes seriously impaired for iron and steel specimens after about one and one-half hours

PLATE VI
Magnification 4300 X

SUBJECT:	A Nickel-iron Alloy.
ETCH:	Forty minutes in a solution consisting of 10 cubic centimeters Nitric Acid, 7.5 cubic centimeters Glacial Acetic Acid and 2.5 cubic centimeters water.
OBJECTIVE:	Zeiss 2 millimeter Apochromat.
N. A.	1.4.
OCULAR:	Zeiss Compensating K-18, 20 X.
FILTER:	Wratten "E" 5600 A. U. to Red End to Secure Contrast.
PLATE:	Wratten "M."
EXPOSURE:	20 seconds.

This is a further development of the crystal structure illustrated in Plate V.

and its effect becomes quite noticeable at 6000 diameters after about thirty minutes. As the contrast decreases due to the tarnishing effect the specimen becomes "flat" in appearance and a good focus is difficult to obtain. For this reason it has been found necessary to photograph the specimen immediately after etching.

Effect of Vibration Overestimated

Vibration has been blamed for many indistinct photomicrographs, and elaborate precautions are often recommended to offset the effect. This trouble appears to be greatly exaggerated. If the

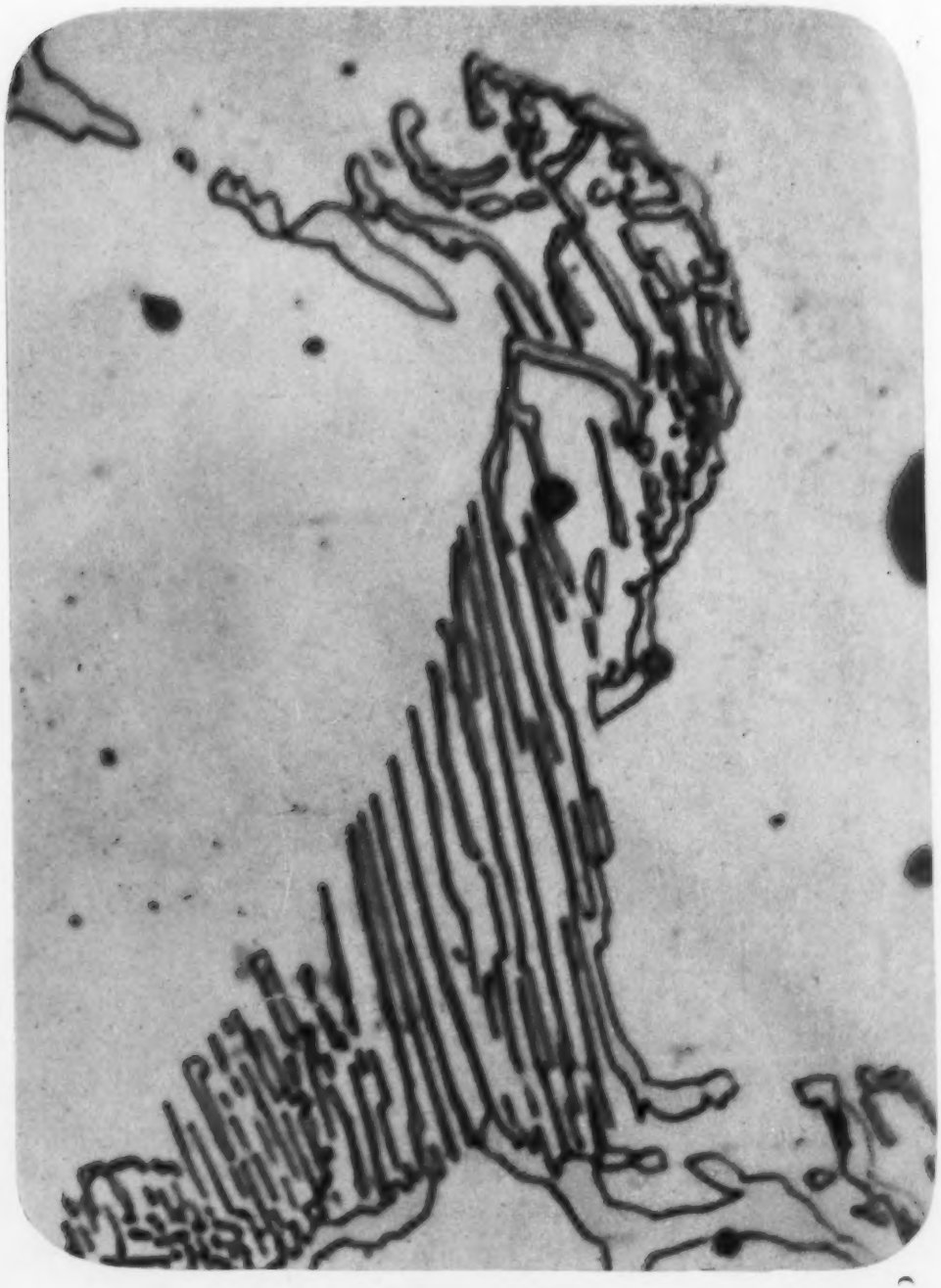

PLATE VII
Magnification 3500 X

SUBJECT: Normal Structure 0.10 per cent Carbon Steel.
ETCH: 5 per cent Solution Picric Acid in Alcohol. A progressive etch to develop contrast.
OBJECTIVE: Zeiss 2 millimeter Apochromat.
N. A. 1.4.
OCULAR: Projection Eye-piece P-4.
FILTER: Wratten "H" 4200 to 5400 A.U.
PLATE: Wratten Panchromatic.
EXPOSURE: 40 seconds.

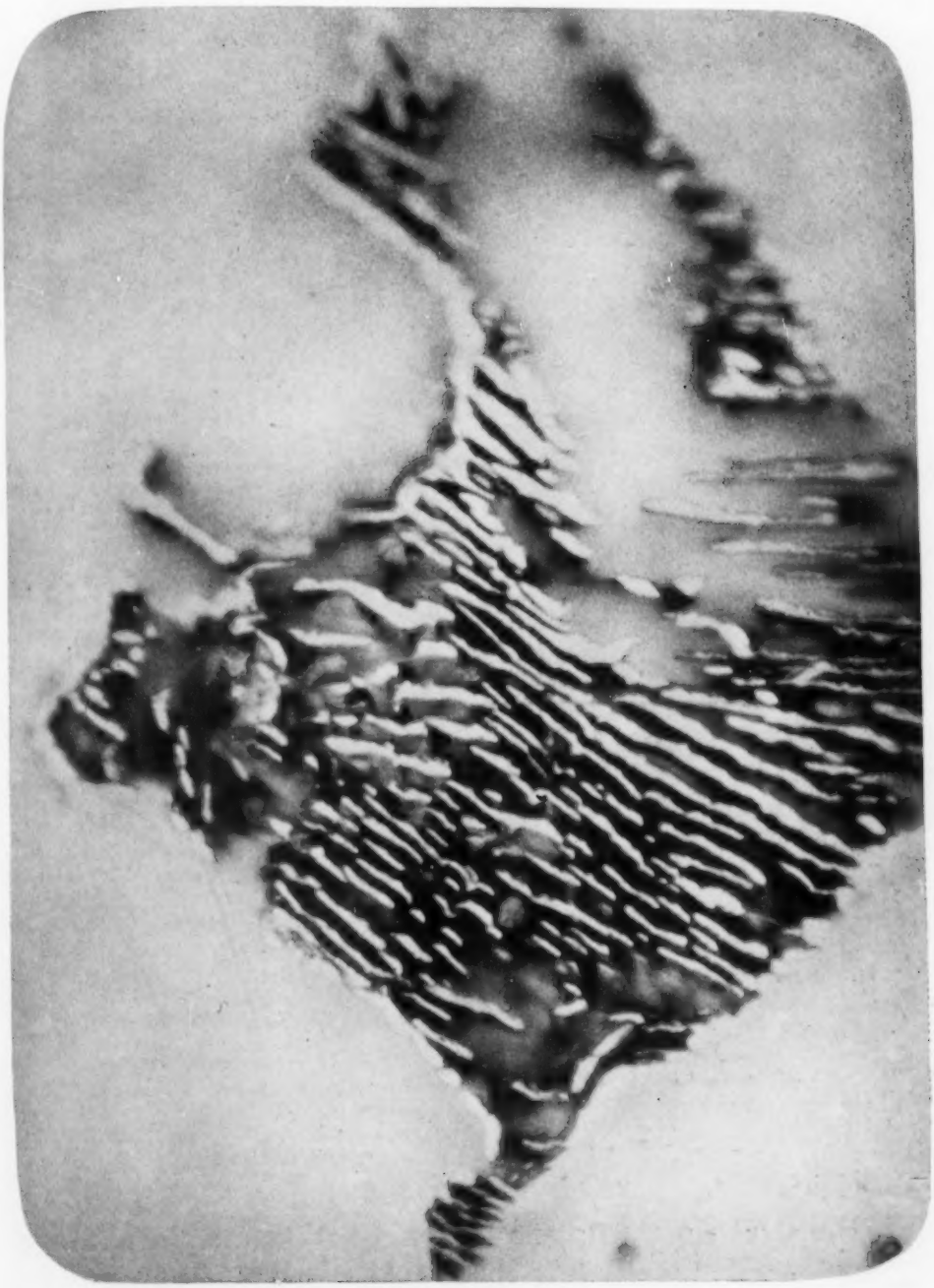

PLATE VIII

Magnification 3000 X

SUBJECT: Normal Structure 0.10 per cent Carbon Steel.
ETCH: 5 per cent Solution of Picric Acid in Alcohol.
OBJECTIVE: Zeiss 2 millimeter Apochromat.
N. A. 1.4.
OCULAR: Projection P-4.
FILTER: Wratten "C" 4000 to 5100 A.U.
PLATE: Wratten Panchromatic.
EXPOSURE: 22 seconds.

Prolonged etching dissolves the ferrite but does not affect the cementite. The latter stands out in relief and under high powers this treatment shows very clearly the form of the cementite plates.

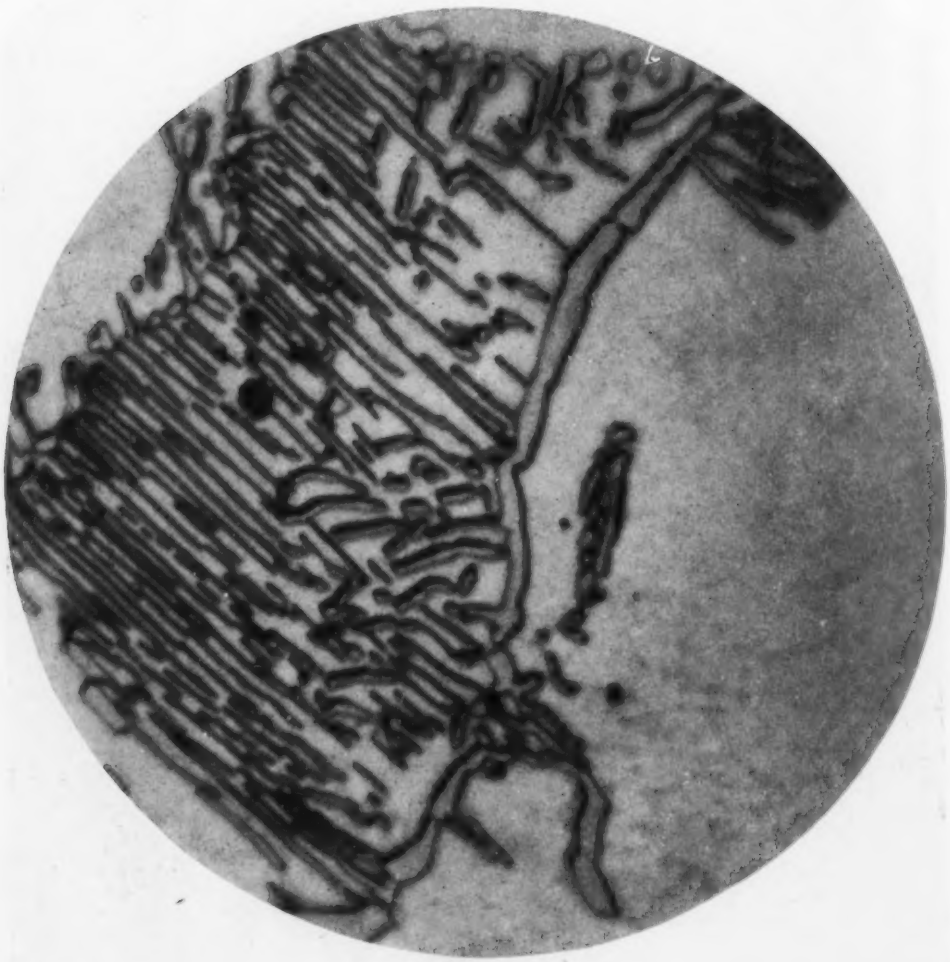

PLATE IX

Magnification 3500 X

SUBJECT: Normal Structure 0.20 per cent Carbon Steel (Pearlite Area).
ETCH: 5 per cent Solution Picric Acid in Alcohol.
OBJECTIVE: Zeiss 2 millimeter Apochromat.
N. A. 1.4.
OCULAR: Projection P-4.
FILTER: Wratten "C" 4000-5100 A.U.
PLATE: Wratten Panchromatic.
EXPOSURE: 25 seconds.

See Plate X for same field at 9000 X.

specimen is properly prepared (polished) and etched so that it can be focussed sharply and if it is photographed immediately, experience in our laboratory seems to indicate that ordinary vibrations such as those encountered in the usual steel frame building are of small importance and can be overcome readily by sponge rubber pads underneath the supporting legs of the stands. This means that people walking nearby; distant machine tools in operation or other dis-

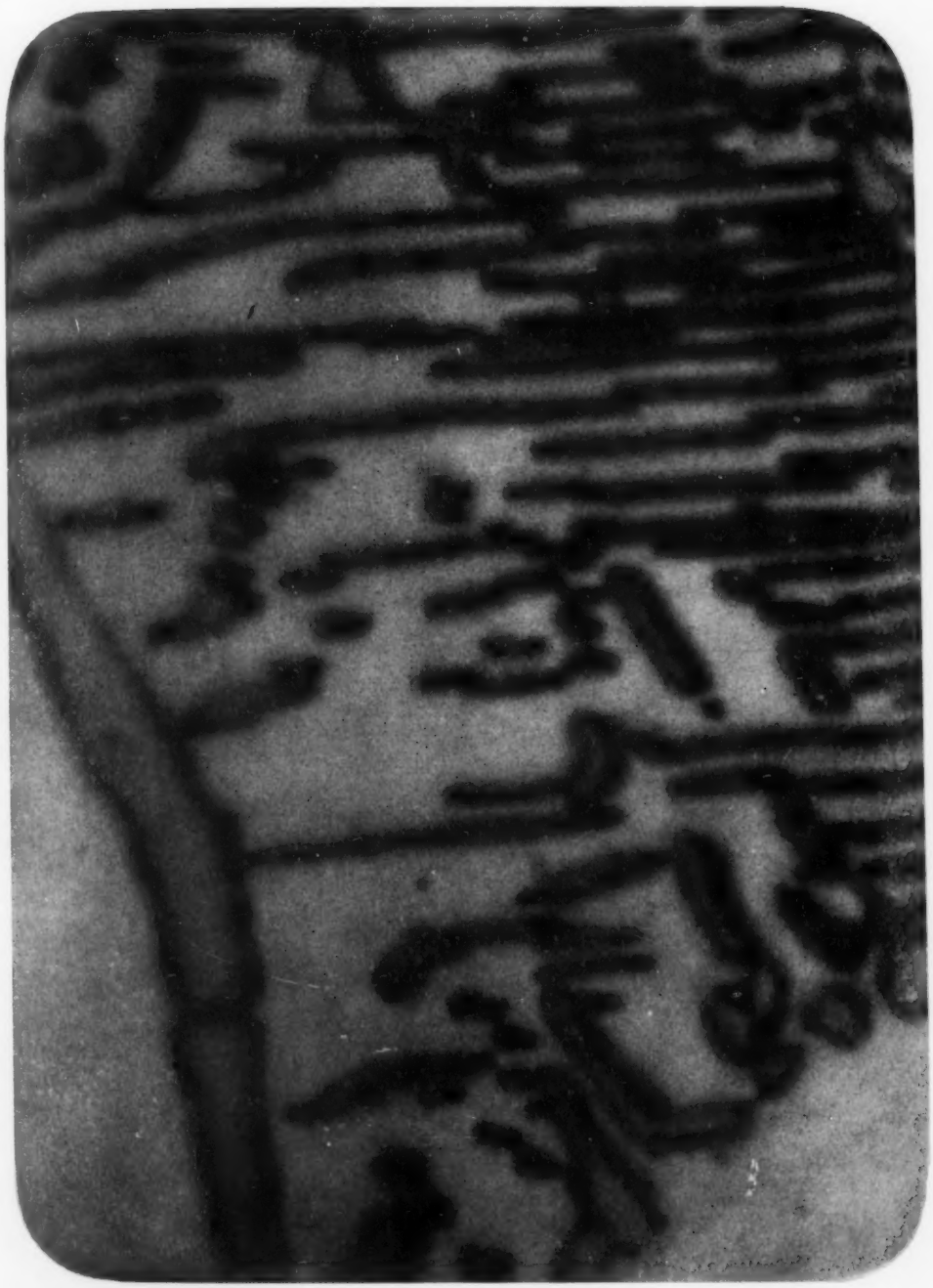

PLATE X
Magnification 9000 X

SUBJECT: Normal Structure 0.20 per cent Carbon Steel (Pearlite Area).
ETCH: 5 per cent Solution of Picric Acid in Alcohol.
OBJECTIVE: Zeiss 2 millimeter Apochromat.
N. A. 1.4.
OCULAR: Zeiss Compensating K-12, 15 X.
FILTER: Wratten "B" 4000 to 5100 A.U.
PLATE: Wratten Panchromatic.
EXPOSURE: 45 seconds.

See Plate IX for same field at 3500 X. This specimen yielded a very brilliant image, consequently a rather short exposure could be made. Even at this extreme magnification it can be seen that the specimen is very highly polished. However, the technique of etching for high-powers, and the need for photographing at once was not fully appreciated or understood when Plates IX and X were taken. In consequence, it is probable that better results might be obtained if these pictures were to be retaken with the knowledge acquired by later developments in the art.

PLATE XI
Magnification 520 X

SUBJECT:	Normal Structure of Eutectoid Steel.
ETCH:	10 per cent Solution Nitric Acid in Alcohol.
OBJECTIVE:	Zeiss 8 millimeter Apochromat.
N. A.	0.65.
OCULAR:	P-4 Projection Eye-piece.
FILTER:	Wratten "C" 4000 to 5100 A.U.
PLATE:	Wratten Panchromatic.
EXPOSURE:	8 seconds.

The object of this photomicrograph is to illustrate at medium-power the same specimen which is shown at higher powers in Plate XII.

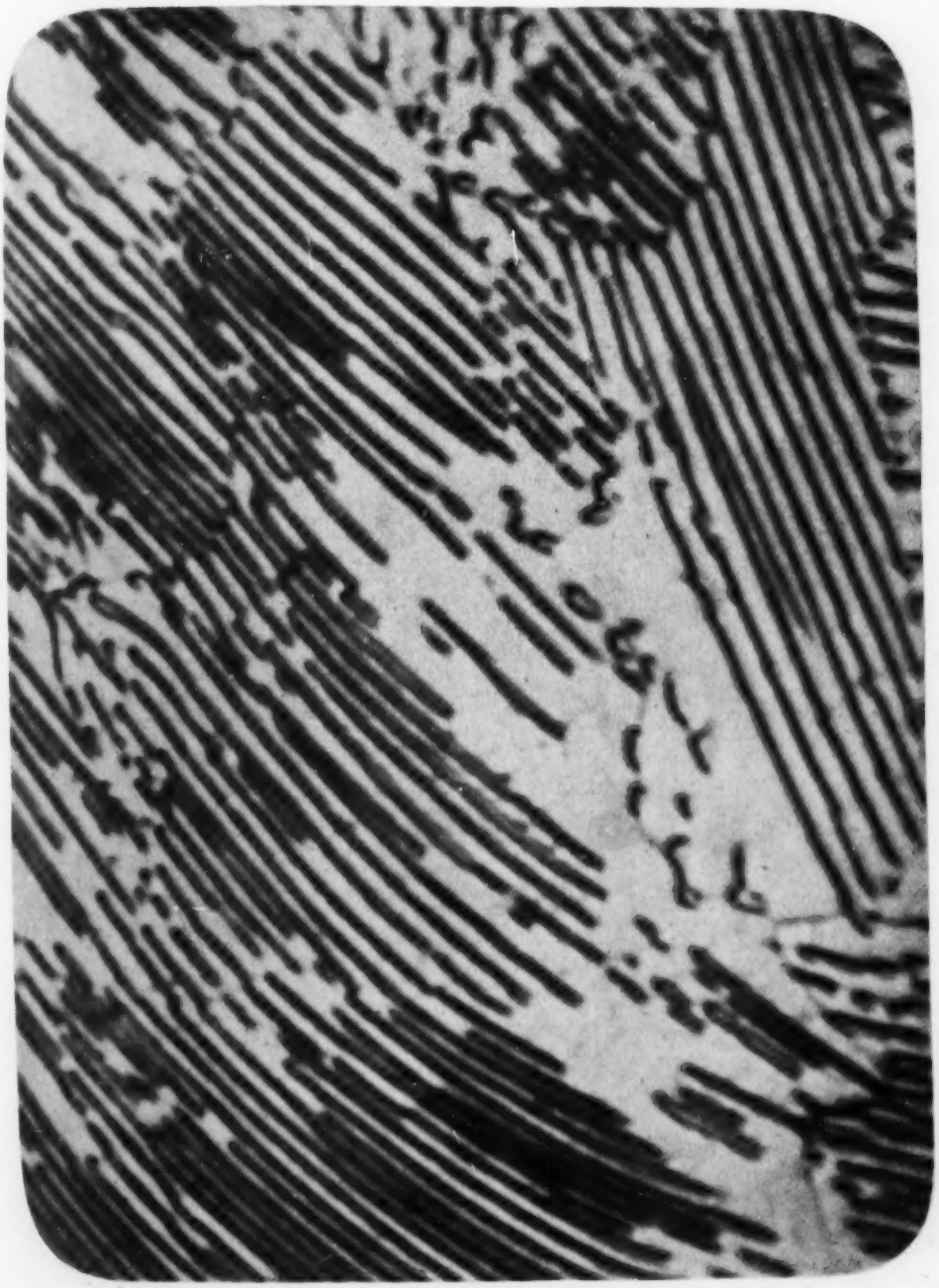

PLATE XII

Magnification 6000 X

SUBJECT: Normal Structure Eutectoid Steel.
ETCH: 5 per cent Solution Nitric Acid in Alcohol. A progressive etch to develop contrast.
OBJECTIVE: Zeiss 2 millimeter Apochromat.
N. A. 1.4.
OCULAR: Zeiss Compensating K-8, 10 X.
FILTER: Wratten "C" 4000 to 5100 A.U.
PLATE: Seeds "L" Ortho.
EXPOSURE: 75 seconds.

The same specimen as illustrated at lower magnification in Plate XI. This photomicrograph offers some interesting possibilities in the way of measuring the dimensions of very small details. For instance, the ferrite plates for this and several other fields taken at the same time average about 1-20,000 inch in thickness and the cementite plates about 1-30,000 inch. The grain boundaries in this plate are defined clearly and measure 1-250,000 inch in thickness.

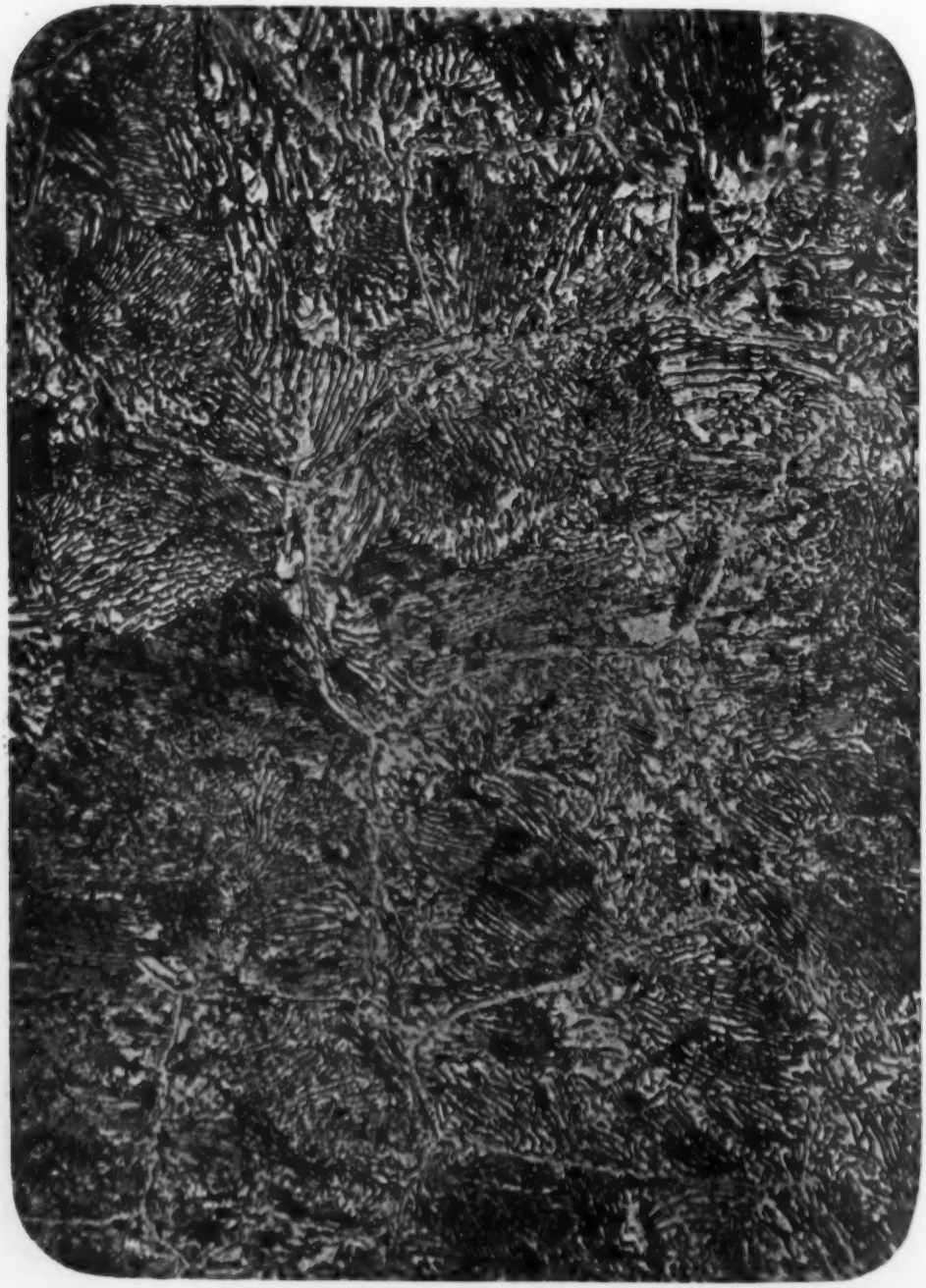

PLATE XIII
Magnification 520 X

SUBJECT: Normal Structure of 1.5 per cent Carbon Steel.
ETCH: 10 per cent Solution of Nitric Acid in Alcohol.
OBJECTIVE: Zeiss 8 millimeter Apochromat.
N. A. 0.65.
OCULAR: Projection Eye-piece P-4.
FILTER: Wratten "C" 4000 to 5100 A.U.
PLATE: Wratten Panchromatic.
EXPOSURE: 8 seconds.

The object of this photomicrograph is to illustrate the structure at medium-power. See Plate XIV for the same specimen at 6000 X.

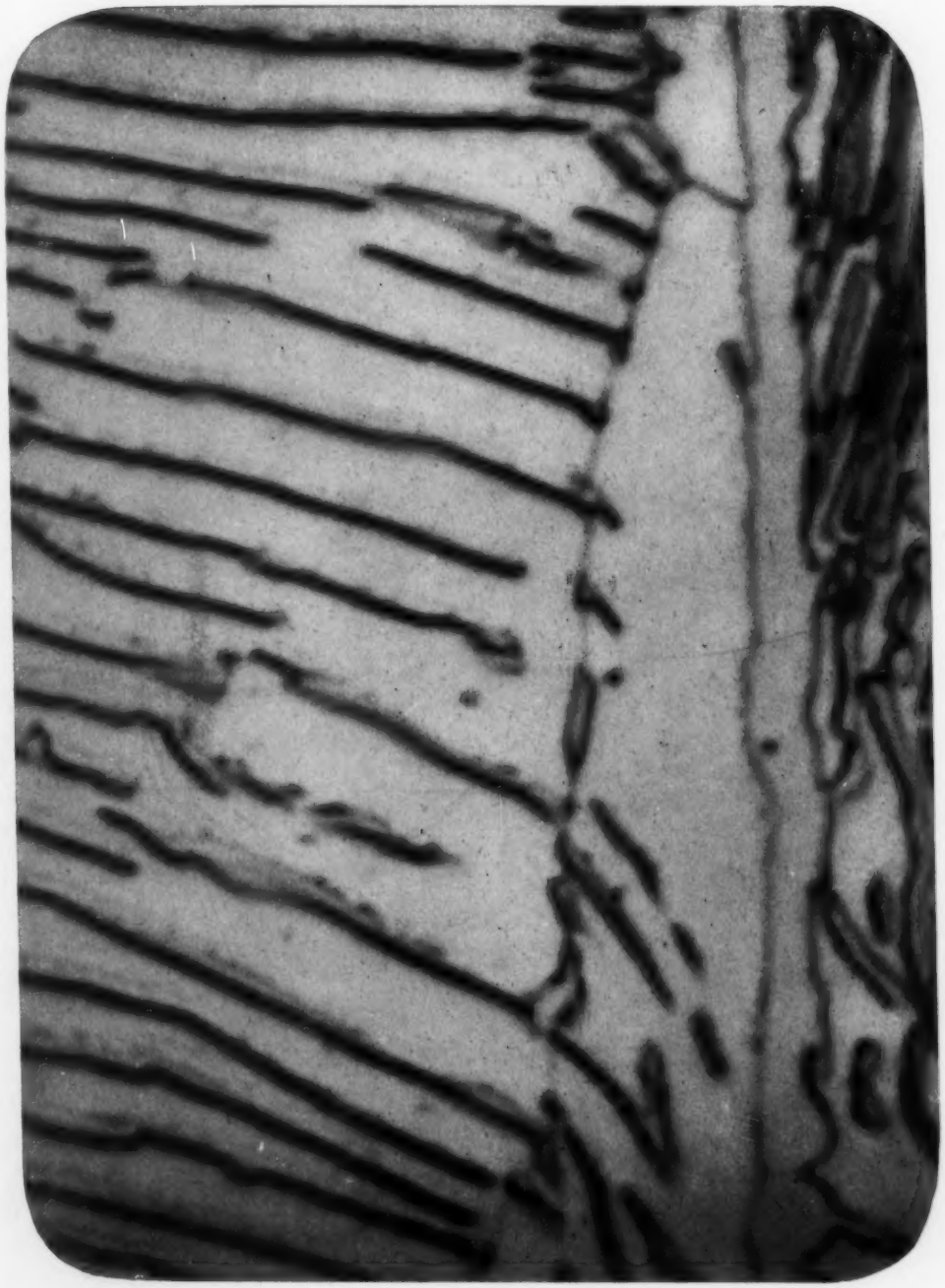

PLATE XIV

Magnification 6000 X

SUBJECT: Normal Structure 1.5 per cent Carbon Steel.
ETCH: Two dips in 3 per cent solution of Picric Acid in Alcohol and one dip in a 1 per cent solution of Nitric Acid in Alcohol.
OBJECTIVE: Zeiss 2 millimeter Apochromat.
N. A. 1.4.
OCULAR: Zeiss Compensating K-8, 10 X.
FILTER: Wratten "H" 4200 to 5400 A.U.
PLATE: Wratten Panchromatic.
EXPOSURE: 1 minute, 52 seconds.

The same specimen as illustrated in Plate XIII at 520 X. High magnification brings out the grain boundary and the free cementite at the grain boundary. The depth of the etching in the ferrite plates is evident.

PLATE XV
Magnification 24 X

SUBJECT: Cast Cobalt of High Purity.
ETCH: Aqua Regia and re-etched with Ferric Chloride and Hydrochloric Acid.
OBJECTIVE: Zeiss 50 millimeter micro-planar.
OCULAR: None.
FILTER: Wratten "C" 4000 to 5100 A.U.
PLATE: Wratten "M."
EXPOSURE: 25 seconds.
ILLUMINATION: Oblique Light.

Before etching, this specimen showed a perfectly polished surface at 400 diameters. It is of interest to note the angular relationship of the lines developed by etching, and to compare these with the orientation and crystal formation developed at higher magnifications in Plates XVI to XIX, inclusive.

PLATE XVI
Magnification 2950 X

SUBJECT: Cast Cobalt of High Purity.
ETCH: Aqua Regia and re-etched with Ferric Chloride and Hydrochloric Acid.
OBJECTIVE: Zeiss 2 millimeter Apochromat.
N. A. 1.4.
OCULAR: Zeiss Compensating K-12, 15 X.
FILTER: Wratten "C" 4000 to 5100 A.U.
PLATE: Wratten "M."
EXPOSURE: 25 seconds.

A portion of one of the crystal grains shown in Plate XV.

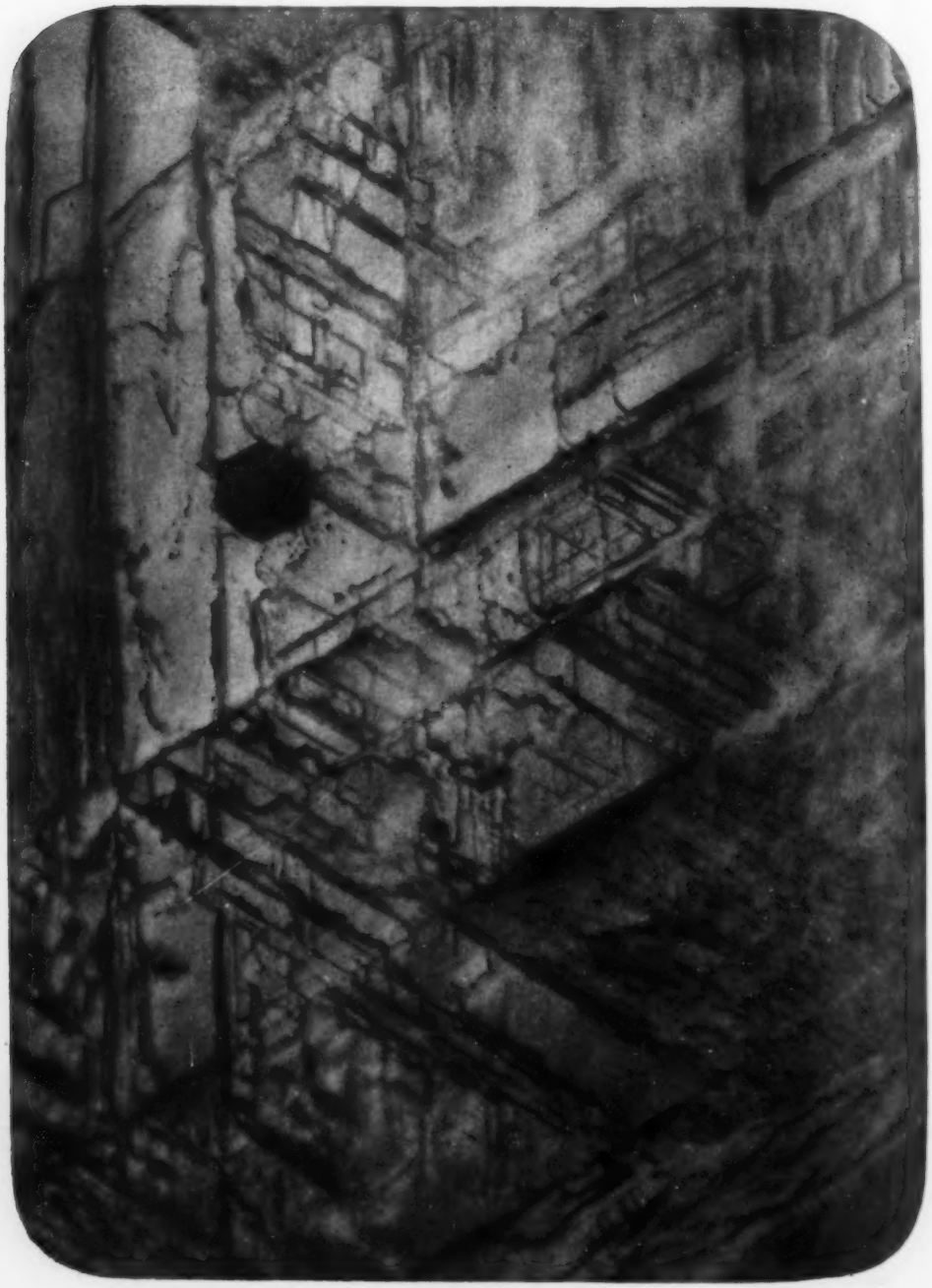

PLATE XVII
Magnification 1600 X

SUBJECT: Cast Cobalt of High Purity.
ETCH: Aqua Regia and re-etched with Ferric Chloride and Hydrochloric Acid.
OBJECTIVE: Zeiss 3 millimeter Apochromat.
N. A. 1.4.
OCULAR: Zeiss Compensating K-8, 10 X.
FILTER: Wratten "D" and "H." Dominant Wave Length 4500 A.U.
PLATE: Wratten "M."
EXPOSURE: One and one-half minutes.

This photograph shows a further development of the crystalline structure of pure Cobalt. The pattern resolves itself into hexagons, equilateral triangles and rhomboids, which appear to be indicative of crystallization in the cubic and the hexagonal systems.

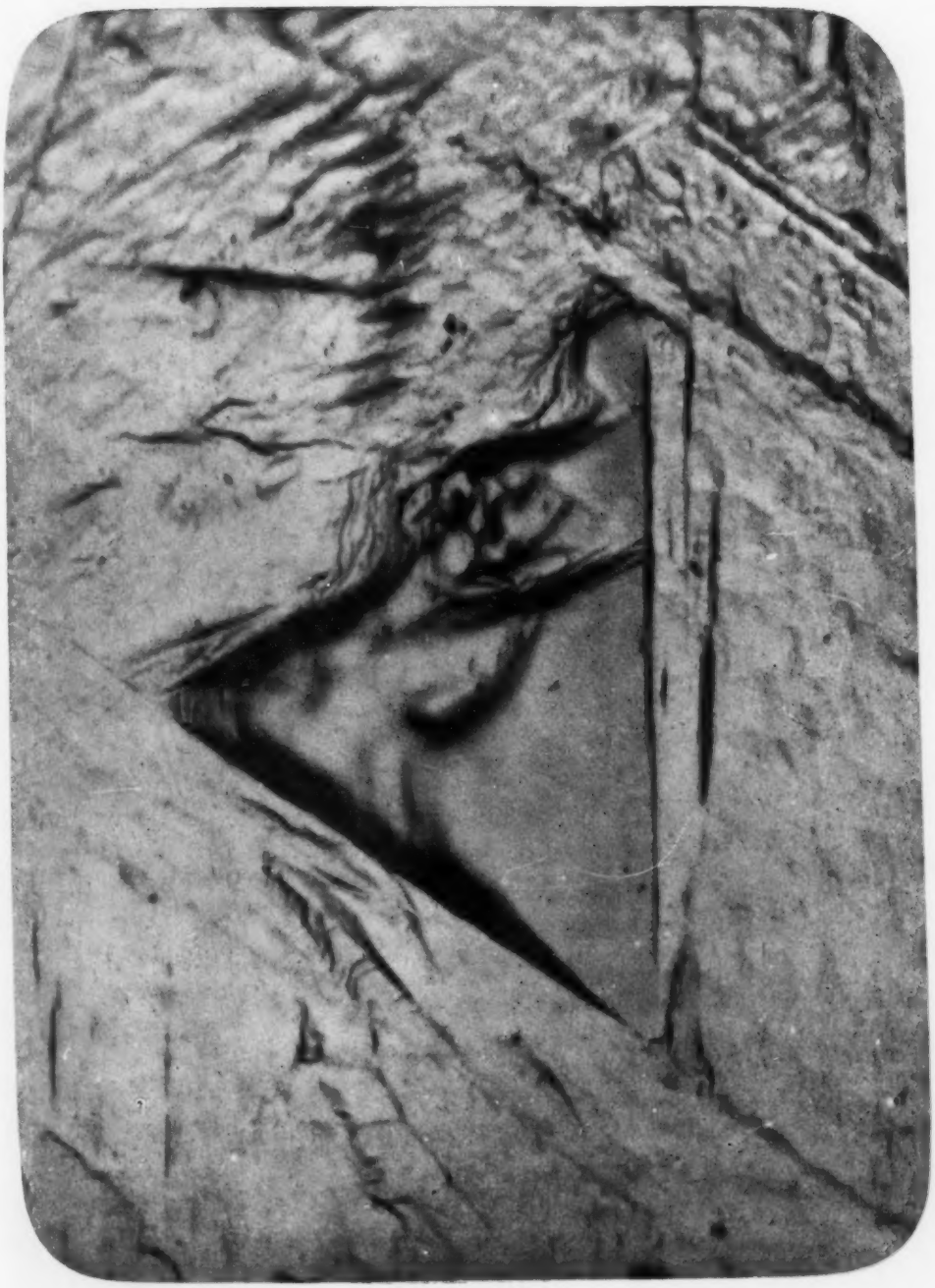

PLATE XVIII
Magnification 2950 X

SUBJECT: Cast Cobalt of High Purity.
ETCH: Aqua Regia and re-etched with Ferric Chloride and Hydrochloric Acid.
OBJECTIVE: Zeiss 2 millimeter Apochromat.
N. A. 1.4.
OCULAR: Zeiss Compensating K-12, 15 X.
FILTER: Wratten "C" 4000 to 5100 A.U.
PLATE: Wratten "M."
EXPOSURE: 25 seconds.

A portion of one of the crystal grains shown in Plate XV. The appearance and angular arrangement of the etching pit would seem to indicate that the surface of the specimen corresponds very closely to a cleavage plane.

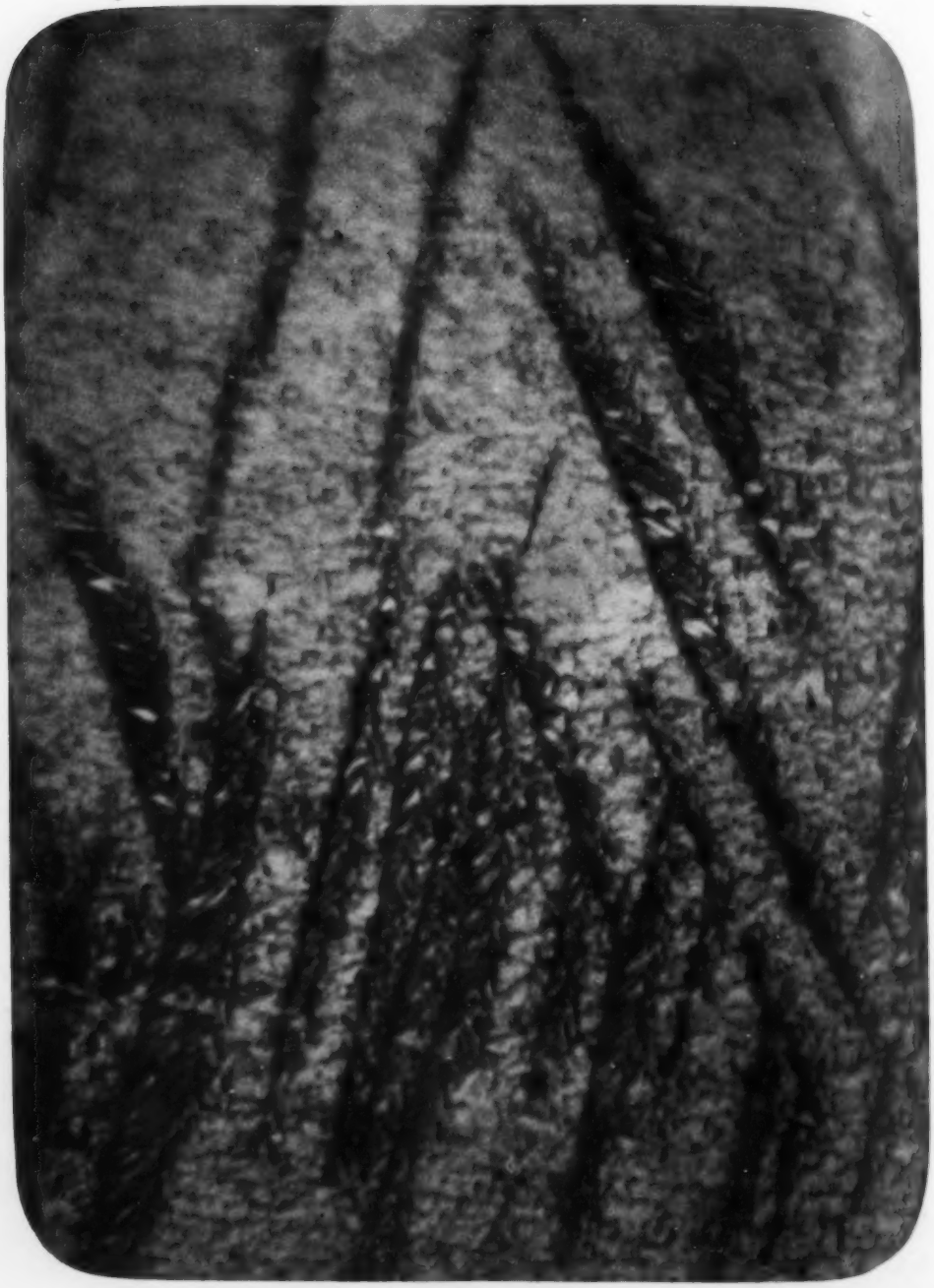

PLATE XIX
Magnification 2950 X

SUBJECT: Cast Cobalt of High Purity.
ETCH: Aqua Regia and re-etched with Ferric Chloride and Hydrochloric Acid.
OBJECTIVE: Zeiss 2 millimeter Apochromat.
N. A. 1.4.
OCULAR: Zeiss Compensating K-12, 15 X.
FILTER: Wratten "C" 4000 to 5100 A.U.
PLATE: Wratten "M."
EXPOSURE: 25 seconds.

This photograph seems to indicate that the Widmanstatten structure has formed and if several of the preceding plates are examined closely, the same structure will be evident.

turbances of slight or moderate intensity can usually be ironed out by a really simple expedient. Because a photomicrograph is "fuzzy" does not necessarily imply that vibration made it so. Polish, etch, tarnish and focus—one or all—may have been responsible.

Exact Focussing Essential

High-power work calls for exact focussing. This is somewhat difficult with the present apparatus because the rigging attached to the fine adjustment for distant control is neither sufficiently slow moving nor exact enough in its adjustment. The objection is not a serious one as refinements in the mechanism are possible. In practice the image first is roughly focussed on a ground glass screen after which the operation is completed on a clear glass screen with the aid of a focussing magnifier. If a dark filter such as a "C" filter or the "D" and the "H" filters together are inserted in the light beam the final focussing can be made with more exactness.

The Value of High-Power Photomicrographs

The question has often been asked, "What do high-power photomicrographs show that cannot be shown by lower magnifications?" The usual answer seems to be that high-power pictures have not added to our store of knowledge although they have constituted an interesting if somewhat "fuzzy" exhibit. According to the writer's way of thinking this is not the real answer.

The fact that secondary structure is not resolved does not necessarily mean that fine structural details do not exist. It does mean that either we do not know how to prepare the surfaces so that these details are differentiated or else the separation is beyond the resolving power of the objective and the light. Negative results do not signify that our knowledge has not been augmented. So far as metallurgical work is concerned, it seems probable that the possibilities of the finest objectives now available are far beyond our ability to use them to best advantage. When we have learned how to improve our method for preparing and for etching specimens it is possible that an entirely new field of investigation will be open to us.

The photomicrographs accompanying this paper were taken by

the writer in the Bell System laboratories of the American Telephone and Telegraph Co. and the Western Electric Co., Inc., New York City. Some of the pictures are of the same subject but at progressively higher magnifications so that the effect of magnification may be evident. They were selected as representative of a large number taken in the course of our work throughout a period of several years. All were taken in connection with definite engineering problems in order that the knowledge derived might enable us to secure better materials.

Conclusion

In this paper it has been the author's object to show somewhat generally the possibilities of high-power metallography as applied to industrial problems. With each picture there is included a brief description and data pertaining to the specimen, its preparation, the optical parts, and the wave-length of the light used. In each case the magnification was determined accurately by means of a high-power stage micrometer.

THE EFFECT OF SILICON ON THE THERMAL CRITICAL POINTS OF STEEL

By F. L. Meacham

Abstract

The effect of silicon on the A1 point of steel is to raise the Ac1 point 28.1 degrees Cent. and the Ar1 point 28.9 degrees Cent. per cent of silicon. The effect on the A2 point of steels under 0.29 per cent carbon is to lower the point by 11.1 degrees Cent. per cent silicon. The carbon content of the steel apparently has a marked effect on the A2 point in ferro-silicon alloys. The A3 point is difficult to follow in silicon steels since silicon diminishes the intensity of the point very rapidly. A method employing the change in electrical resistance at the A3 point, points toward a possible method of following the transformation further than it has previously been followed.

Object of the Investigation

THE object of this investigation was to determine the effect of silicon on the thermal-critical points of steel. That is to say, to ascertain the position of the points A1, A2, and A3 in iron-carbon-silicon steels and to compare the position of these points with those of pure iron-carbon alloys.

History

This subject is one upon which comparatively little work has been done. The oldest authoritative reference which was found was that of W. Gontermann of Victoria University, Manchester. His work was performed principally by taking cooling curves of various samples, and by studying quenched specimens under the miscroscope. He states that his method of taking cooling curves was not a particularly sensitive one and that the only

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A thesis presented in partial fulfillment of the requirements for the degree of Bachelor of Science in Metallurgical Engineering at Case School of Applied Science, June 1923. Experimental work conducted in the Research Department of the National Malleable Castings Co., Cleveland, O.

transformation which he had been able to investigate thermally was that of the formation of pearlite, or the A1 point.

Charpy and Cornu-Thenard also did some work along this line, the results of which were published in Vol. XCI of the *Journal* of the Iron and Steel Institute in 1915. The following is a summary of their results.

Influence of silicon on the A1, A2 and A3 points:

They were able to confirm, as other observers had pointed out, that the A3 point rapidly decreases in intensity when the percentage of silicon increases, at the same time rising on the temperature scale. The temperature at which the A1 perturbation takes place rises with the silicon percentage, this point reaching, and then passing the A2 point while becoming gradually fainter. After reaching a given percentage of the metalloid and for a given rate of variation of the temperature, the A1 point completely disappears, and all the carbon of the steel is found in the state of graphite.

The A2 point falls gradually in the temperature scale as the percentage of silicon rises, losing little by little its intensity the while, but still persisting in a very clear manner in metals containing up to 7 per cent of the metalloid. At this percentage of silicon, the A2 point is the only abnormality which appears upon thermal investigation, in alloys containing low carbon, even when the rate of variation in temperature be sufficiently accelerated.

The most recent work which has been done on this subject, exclusive of the present investigation, is that of Howard Scott of the Bureau of Standards. His work in connection with ferrosilicon alloys was done on steel of about 0.45 per cent carbon content. The manganese averaged about 0.70 per cent. Ac1 is raised 21 degrees centigrade and Ar1 raised 18 degrees Cent. for each per cent of silicon added up to at least 3 per cent, while A2 is lowered 21 degrees Cent. for the same increment.

Description of Apparatus

Crucibles

A satisfactory crucible in which to melt the samples was a source of much trouble at the beginning of the experiment. The

crucible which was finally used and which gave good results was made by lining a graphite shell with magnesia.

Furnace

The furnace used for melting was a horizontal granular carbon resistance type.

Current to the furnace was supplied by a transformer at a maximum of 90 volts. Control of this furnace was accomplished by means of an induction voltage regulator connected into the power line, ahead of the transformer.

Casting

Casting was done in a box filled with ordinary molding sand properly tempered and packed. The test pieces were made about ½ inch in diameter, 2½ to 3½ inches long, depending upon the amount of material melted. These castings were allowed to cool in the sand. When cold they were removed, cleaned and machined, the turnings being saved for chemical analysis.

Transformation Point Apparatus

The equipment used for this purpose was a regular type transformation point recorder, as manufactured by the Leeds and Northrup company.

Electrical Resistance Apparatus for Locating A3

In an effort to locate the A3 point and follow it further than it had previously been followed in the iron-carbon-silicon alloys another method was tried. This method, suggested by H. A. Schwartz (modified from Honda), employs the principle that the A3 transformation is accompanied by a marked change in electrical resistance.

The specimens for use were machined into the shape of bars with a rectangular cross section ⅛ by ½ by 3¼ inches long. The samples examined, were joined at one end to a bar of Armco (nearly pure) iron of the same dimensions. The samples thus mounted were connected as shown in Fig. 1.

In Fig. 1, I represents a bar of Armco iron and S the steel sample. These two bars are joined at A, from which point a lead is taken to one side of the difference galvanometer of the transformation point apparatus.

Current is supplied by the battery B, which is conducted to the bars by iron wires connected to the samples at the points C and C¹. Another set of lead wires are connected to the specimens at the points E and E¹. These wires lead to the variable resistance R1 and R2. From the point F another lead is taken to the difference galvanometer DG.

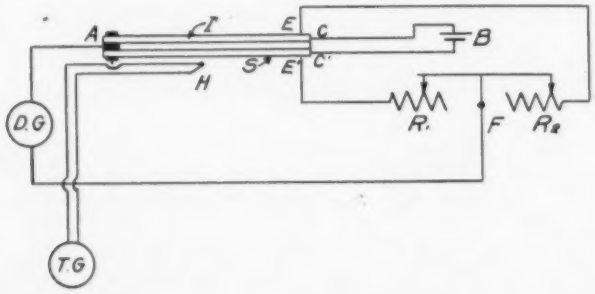

Fig. 1—Showing Method of Connecting Specimens for Obtaining Their Change in Electrical Resistance.

When the battery B is connected and the resistance R1 and R2 properly balanced, no curent will flow through the circuit F, DG, A. If the resistance of either bar, the Armco iron or the steel, changes, a current will flow through that branch of the circuit and thus deflect the galvanometer in a direction depending upon which bar changes resistance. Thus, when the apparatus so arranged and balanced, is heated through the critical range of one of the bars, a deflection will be produced in one direction. This deflection will be counteracted when the other specimen reaches its transformation point and changes resistance, provided that the resistance of both bars changes in the same direction.

The temperature of the specimen is measured by placing a thermocouple close to the specimen at the point H. This is then connected to the potentiometer of the transformation point equipment. By this procedure both the temperature and the change of resistance could be recorded directly upon the regular type of chart used with this equipment.

The type of curve which would be expected from this procedure is shown in Fig. 2. The slope of the line AB is due to a slow but constant heating of the specimen accompanied by a gradual and slightly differential change in resistance of the specimen. When the transformation point of one of the bars is

reached such as the point B, a change in resistance occurs which is accompanied by the corresponding deflection BC. When the transformation has completed itself the course of the curve will be along the line CD, practicaly parallel to, or in the same gen-

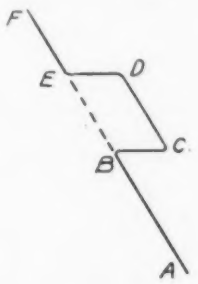

Fig. 2—Type of Curve to be Expected from Tests Made with Apparatus in Fig. 1.

eral direction as AB. When the transformation point of the second bar is reached, its resistance changes and is accompanied by the deflection DE. If these deflections should happen to occur at the same temperature and the amount by which the resistance changes be the same, no deflection would occur and we would have the straight line ABEF.

Upon repeated heating and cooling the deflection corresponding to the A3 point for the Armco iron should always occur at the same temperature. By using different steel samples with varying silicon content, the position at which the deflection due to the A3 point in the steel occurs will move up or down the temperature scale. Thus, by making a series of these curves it should be possible to trace the path of the A3 point as it changed its position, due to the silicon and carbon of the steel.

Detailed Account of Method of Procedure

The samples tested were prepared from Armco iron, ferrosilicon and washed metal, melted together in the proper proportion to give the desired chemical analysis. Four series of samples were selected, each series having a different carbon content, ranging from 0 to 0.75 per cent, namely 0, 0.25, 0.50 and 0.75 per cent. For each of these carbon percentages, samples were prepared with silicon contents approximately 0, 0.50, 1.00, 2.00, 3.00 and 4.00

per cent. Considerable difficulty was experienced in making specimens of the desired compositions.

When the calculated amounts of each material had been charged into the hot crucible and allowed to melt, they were

Table I

Chemical Composition and Thermal-Critical Points of Steels Tested

Carbon Per cent	Silicon Per cent	Critical Points—Degrees Fahrenheit Ac1	Ar1	A2	Sample Number
		Series-1			
0.26	0.07	1340	1300	1405	700
0.26	1.20	1400	1310	1395	24
0.10	5.00	1595	1530	1330	15
		Series-2			
0.38	0.39	1330	1305	1350	20
0.38	0.54	1335	1310	1350	19
0.34	0.63	1385	1310		705
0.38	2.03	1460	1360	1390	520
0.30	4.35	1640	1590	1350	540
		Series-3			
0.48	1.48	1400	1300	1370	18
0.47	2.25	1395	1250	1290	710
0.52	3.45	1510	1400	1380	14
0.44	3.90	1530	1440	1365	16
		Series-4			
0.64	1.80	1410	1390	1390	720
0.64	2.45	1475	1380		17
0.59	4.03	1510	1510	1220	740
0.58	0.66	1370	1310	1345	23
		Series-5			
1.32	0.01	1300	1330		10
0.72	0.25	1340	1300		21
0.94	0.45	1360	1305		11
1.02	1.00	1400	1400		12
		Series-6			
0.74	1.90	1445	1390	1415	13
0.70	1.92	1450	1370	1420	22

vigorously stirred with a soft iron wire and then allowed to remain in the furnace for about ten minutes, so as to insure thorough mixing of the different materials charged.

When ready to pour, the current was turned off from the furnace and the crucible removed with a pair of tongs. The liquid melt was then poured into a mold made with ordinary molding sand. All analyses are recorded in Table I.

Thermocritical curves were taken on all of the samples made. It proved impossible, however, to follow the A3 transformation with the transformation equipment, so it was decided that a series of cooling curves should be taken on liquid low carbon samples of different silicon content. This procedure was tried by melting up material of the desired composition and then

placing a thermocouple in the bath, the couple being protected by a fused quartz tube. This method did not prove to be a suc-

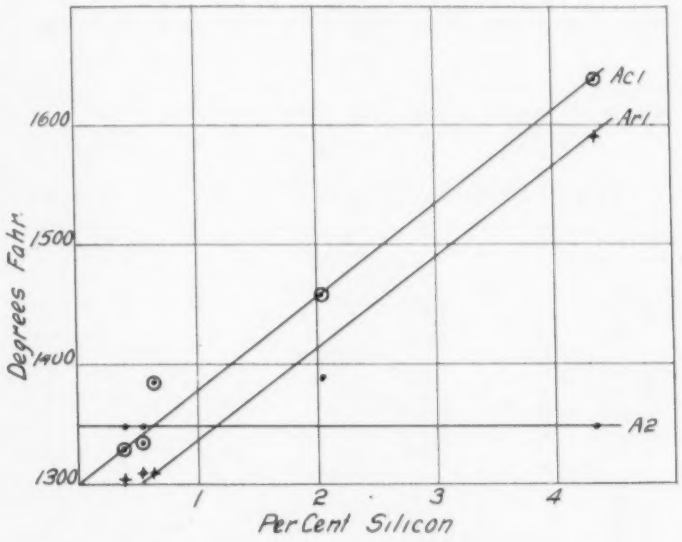

Fig. 4—Showing the Effect of Various Amounts of Silicon on the Critical Points of a 0.30 to 0.40 Per cent Carbon Steel.

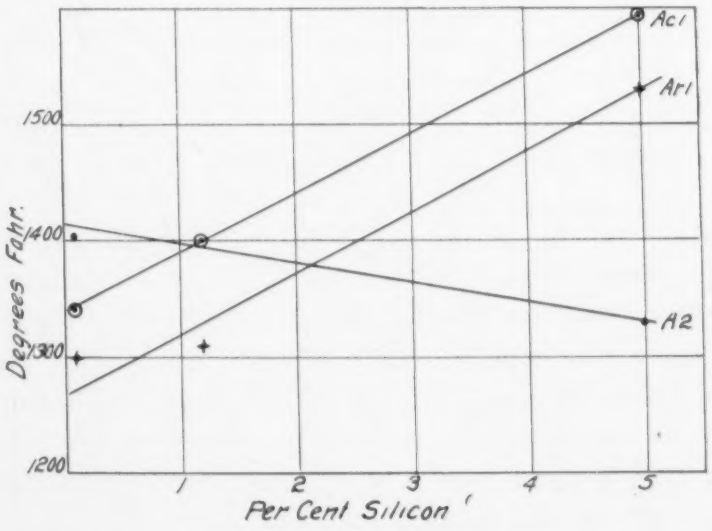

Fig. 3—Showing the Effect of Various Amounts of Silicon on the Critical Points of a 0.10 to 0.26 Per Cent Carbon Steel.

cess, due to the fact that the rate of cooling was too irregular even though precautions were taken to promote regular cooling. The results from these tests, when plotted, were meaningless for any of the points other than A1.

Discussion and Conclusions

In taking the data incorporated in the results of this investigation the location of the Ac1 and Ar1 points was taken at the

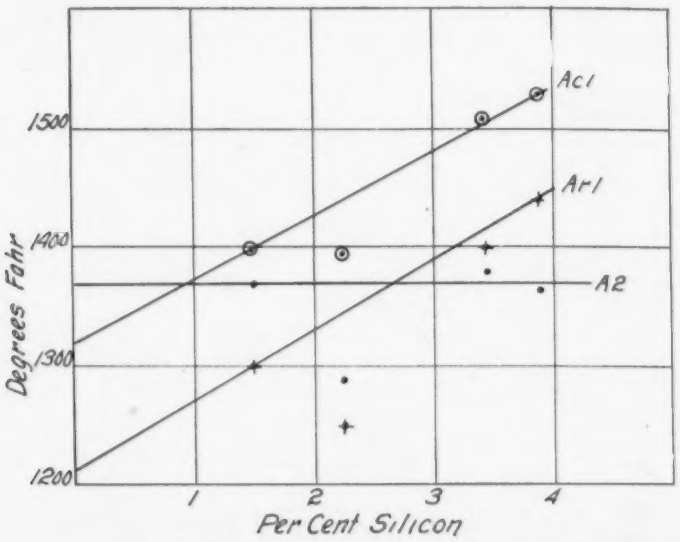

Fig. 5—Showing the Effect of Various Amounts of Silicon on the Critical Points of a 0.44 to 0.52 Per Cent Carbon Steel.

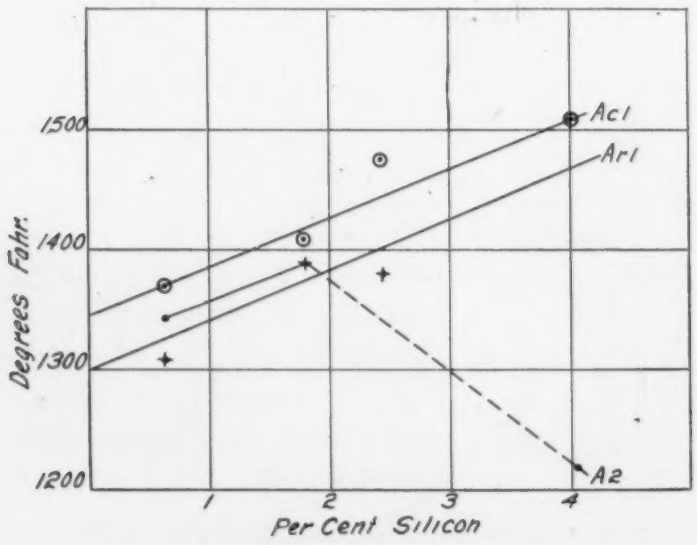

Fig. 6—Showing the Effect of Various Amounts of Silicon on the Critical Points of a 0.58 to 0.64 Per Cent Carbon Steel.

point at which the break in the transformation curve starts. In the interpretation of the A2 point, a different method or system was employed. Due to the characteristic shape of the A2 point

the peak of the break was taken as the temperature of the transformation. There is very little hysteresis in the A2 po'nt, so, consequently, it often happens that the A2 transformation may

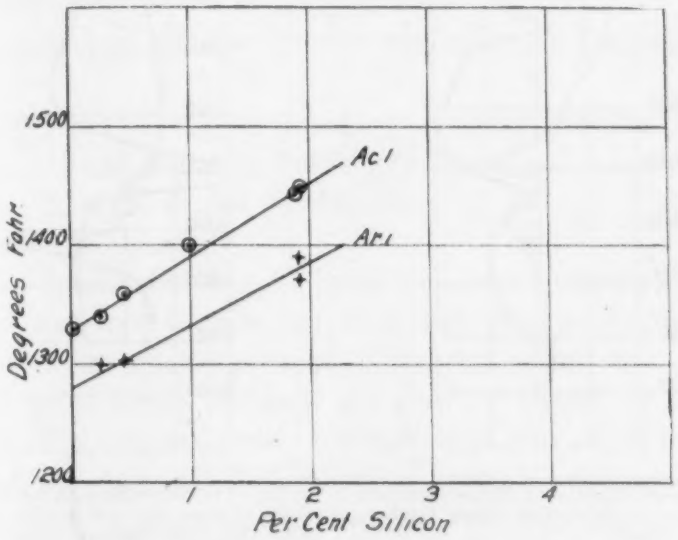

Fig. 7—Showing the Effect of Various Amounts of Silicon on the Critical Points of 0.70 Per cent Carbon Steel.

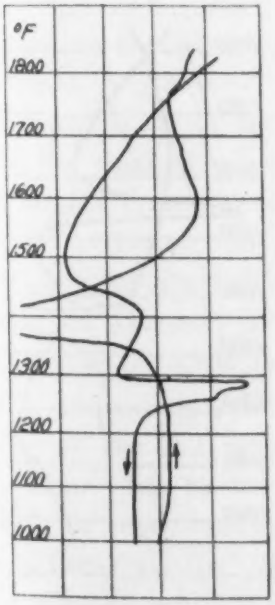

Fig. 8—Reproduction of Transformation Point Curve of a 0.26 Per Cent Carbon, 0.07 Per Cent Silicon Steel.

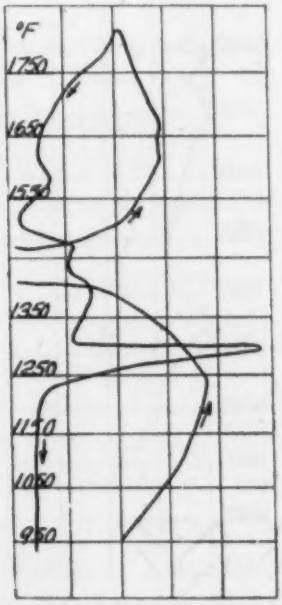

Fig. 9—Reproduction of Transformation Point Curve of a 0.26 Per Cent Carbon, 1.20 Per Cent Silicon Steel.

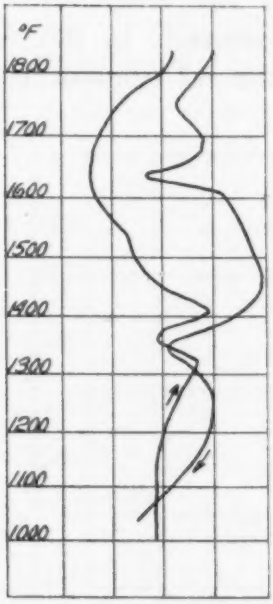

Fig. 10—Reproduction of Transformation Point Curve of a 0.10 Per Cent Carbon, 5.00 Silicon Steel.

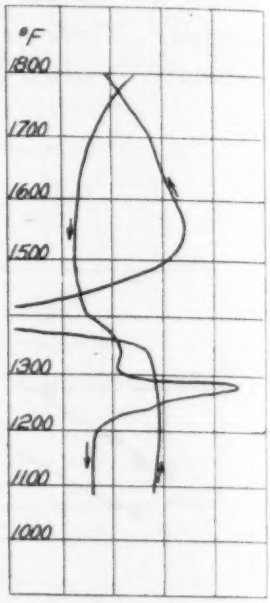

Fig. 11—Reproduction of Transformation Point Curve of a 0.38 Per cent Carbon, 0.39 Per Cent Silicon Steel.

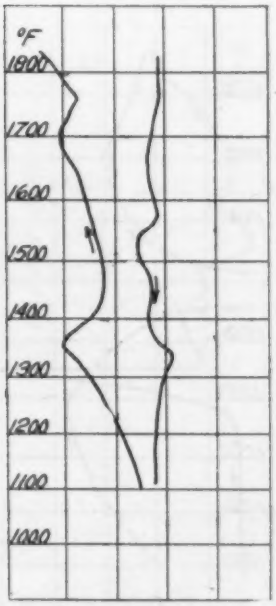

Fig. 12—Reproduction of Transformation Point Curve of a 0.30 Per Cent Carbon, 4.35 Per Cent Silicon Steel. Curve Smoothing out at High Silicon Content.

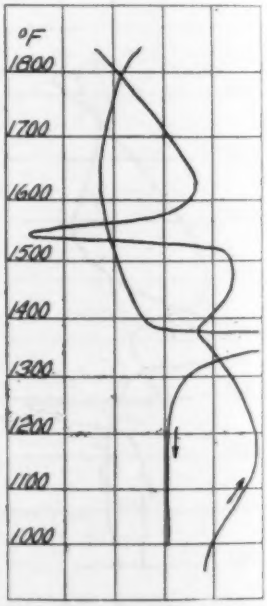

Fig. 13—Reproduction of Transformation Point Curve of a 0.52 Per Cent Carbon, 3.45 Per Cent Silicon Steel.

be hidden in the Ac1 transformation on the heating curve while on the cooling curve the Ar1 transformation will be lowered, due to hysteresis, sufficiently to show the A2 point. If the A2 point was obtained on both the heating and cooling curves it was found that the Ac2 point would be *slightly* above the Ar2 point. In such a case the mean of the two points was taken as the actual critical point.

A tabulation of the temperature at which the Ac1, Ar1, and A2 points occur is found in Table I. When these values are plotted as in Figs. 3, 4, 5, 6 and 7, the effect of silicon on the thermo-critical points is shown.

It was found that the A1 transformation remained a horizontal line in the Iron-Carbon diagram, but was gradually raised in proportion to the silicon content. The Ac1 point rose an average of 28.1 degrees Cent. for each per cent of silicon, while the Ar1 point rose 28.9 degrees Cent. for each per cent of silicon. If the average of the Ac1 and Ar1 points be taken as the position of the A1 point, and a line drawn through this average value, it will intersect the temperature ordinate at 1300 degrees Fahr. or 704 degrees Cent. This is the value for iron obtained from this work and differs from the temperature generally accepted for A1 by only 10 degrees Fahr. or 6 degrees Cent. This small discrepancy is well within the working limits of the apparatus and any personal error which might enter into the results. Figs. 8, 9, 10, 11, 12 and 13 show some of the types of curves obtained.

By the method of interpretation employed for the A2 points of the curves from samples included in Series 1, the effect of the silicon is to lower the point by 11.1 degrees Cent. This value is very close to the value noted by previous investigators with the exception of Howard Scott, whose work was performed on steels of about 0.45 per cent carbon.

The remaining series do not check Series 1 in regard to the lowering of the A2 point. Undoubtedly discrepancies of interpretation occur, due to the range of carbon content of the samples included in each series, inasmuch as the carbon does affect the position of the A2 points in steels. The variation in carbon content cannot be made to account for all the difference in Series 2, 3, and 4, because in these series the difference from Series 1 is too great for the small variation in carbon to produce.

In Series 4, the A2 point tends to rise somewhat as the silicon increases until 2.5 per cent is reached after which point it lowers rapidly. This break in the A2 point was also noted by Charpy in his work on the subject. A2 as noted in the graphs representing Series 2 and 3 is practically horizontal with perhaps a slight tendency to drop.

So far as this problem was carried nothing definite was learned about the A3 point except that with the addition of silicon, it becomes very faint and difficult to find. The method involving the change of electrical resistance points toward a possible method of following the transformation.

The author wishes to express his appreciation to all those who have, in any way assisted him with the work in connection with this investigation. Especially does he wish to thank H. A. Schwartz, director of research of the National Malleable Castings Company, for the privilege of working in his research laboratory, and for the many valuable suggestions made in connection with the problem. Likewise does he wish to express his appreciation to Prof. H. M. Boylston who so willingly co-operated with him in all ways.

(*Continued from Page* 610)

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The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment — Members Submitting Answers and Discussions Are Requested to Refer to Serial Numbers of Questions

NEW QUESTIONS

QUESTION NO. 99. What is the effect of barium carbonate and sodium carbonate in carburizing compounds, on alloy carburizing boxes?

QUESTION NO. 100. What action results from the addition of varying amounts of aluminum and ferrosilicon to steel while casting?

ANSWERS TO OLD QUESTIONS

QUESTION NO. 67. What is the reason for the fact that a piece of steel quenched in brine will be harder than the same piece of steel would be if quenched in water, providing that the quenching temperatures and quenching medium temperatures are the same in each case?

ANSWER. By S. A. Richardson, Department of Engineering, Lewis Institute, Chicago.

The ability of any medium to extract heat from a piece of steel depends upon a combination of certain physical and chemical properties. It is quite generally agreed that these properties are viscosity, boiling or volatilization point, thermal conductivity, density, specific heat, latent heat of vaporization and heat of (chemical) dissociation. The substance possessing the right combination of these properties will be a more drastic quenching medium than a substance not possessing this ideal combination. The actual temperature of the medium, within reasonable limits, may exert but little influence in such a case as outlined in this question.

QUESTION NO. 69. Is sulphur up to 0.10 per cent detrimental to the quality and physical properties of an automotive steel?

QUESTION NO. 72. What elements are conducive to good electric butt-welding of steels?

QUESTION NO. 73. Does electric butt-welding destroy the physical properties developed in a steel which has been heat treated prior to the welding operation?

QUESTION NO. 74. Why shouldn't a bar of steel rolled from a locomotive axle be better than one rolled direct from the billet made from the original ingot?

QUESTION NO. 83. In annealing high-carbon tool steel in an open-fire furnace 6′ x 12′ is it likely that sulphur would be imparted to the steel by the use of producer gas made from coal unusually high in sulphur, say around 1.50 to 2.00 per cent?

QUESTION NO. 85. What is the best method of preventing carburization in holes, or in the bore of parts to be case hardened?

QUESTION NO. 92. What is meant by reduction of area in tensile testing of metals?

ANSWER. By S. A. Richardson, Department of Engineering, Lewis Institute, Chicago.

When specimens of steel are subjected to tensile stress they undergo a decrease in diameter, or cross section at right angles to the direction of the pull. The ratio, after rupture of the bar, between the area at the point of greatest decrease in diameter and

the original area of the specimen, determines the per cent reduction of area. It is a measure of the ductility of the steel.

QUESTION NO. 93. What are the more common methods of quenching ordinary taps? Are they quenched all over and the shanks drawn, or are they quenched only on the threaded portions; or are both the threaded portions and the tangs quenched, leaving the center portion of the shank soft?

QUESTION NO. 94. What are the most salient causes of the explosive disruption of many hardened steel articles?

ANSWER. By S. A. Richardson, Department of Engineering, Lewis Institute, Chicago.

The explosion, or sudden breaking of the steel is caused, of course, by internal stress, which apparently may be produced by two causes. The first condition is observed more often in pieces of considerable mass. It appears that the outer shell of the piece of quenched steel undergoes the changes occurring in the critical range and becomes set before the interior has accomplished these changes, so that the marked expansion that should take place is suppressed in the interior of the steel. The stress set up by the interior of the steel endeavoring to effect this volume change is usually sufficient to burst the piece. In most cases, this can be prevented by placing the piece in the drawing furnace or bath immediately upon its removal from the quenching tank, thus softening the exterior so that it will give without cracking. The same thing may often be done by withdrawing the quenched piece from the bath as soon as the steel is black, so that it may be tempered by its residual heat. The second condition may be due to a nonuniform quenching, nonuniform drawing, or quenching a nonuniformly heated piece. Thus—a properly quenched piece of steel—all martensite—if drawn over only part of its mass will rupture in the same manner. The explanation appears to be that the constituent produced by the drawing, say troosto-sorbite, has a different volume than the constituent of the untempered area, which we have said is martensite. Two

unequal volumes in a piece of steel will set up internal stress sufficient to produce rupture, or in a more ductile steel, to produce warping.

QUESTION NO. 95. What is meant by "self hardening" steels?

ANSWER. By Frank Garratt, superintendent, Latrobe Electric Steel Co., Latrobe, Pa.

In a general sense "self-hardening" steels are those which, by the addition of some element other than carbon become hard when cooled freely in air from, or above, their hardening temperatures.

From this definition it will be seen that "self-hardening" steels may cover a wide range of composition including particularly, certain chromium, nickel chromium, molybdenum chromium, and tungsten chromium steels, and certain combinations of tungsten, chromium, molybdenum, and vanadium. High-speed steel is the most common example of "self-hardening" steels.

While the definition given above may include a large number of steels, some tool steel manufacturers and users have in mind a certain distinct type of steel when the term "self-hardening" is used. This type of steel is the forerunner of the modern high-speed steel, and as compared with the latter is very high in carbon, low in tungsten, and free from vanadium. In certain cases molybdenum has replaced the tungsten addition.

This steel came into use soon after Mushet's discovery that tungsten in combination with carbon and manganese (and later chromium) produced the property of the steel becoming hard on cooling freely in air from the hardening temperature. Owing to this very unusual property, at that time, the steel was called "self-hardening."

As these early types were perfected, resulting in steels of changed compositions and greater cutting capacities, the term "high-speed" steel came into more general use, and the term "self-hardening" was retained to distinguish the early types of cutting tools from the more modern high-speed steels.

Some actual analyses of these early types of "self-hardening" steels are as follows:

Carbon	2.18	1.79	.98	1.42
Tungsten	8.80	7.87	8.75	none
Chromium	1.89	3.72	2.98	3.39
Molybdenum	none	none	none	3.41
Silicon	1.13	.15	.28	...
Manganese	2.24	.28	.39	...

It should be understood, of course, that the term "self-hardening" is used in a relative sense, since the sections treated naturally influence the rate of cooling, and the degree of hardness acquired (which must also be taken into consideration) is dependent to a certain extent upon such rates of cooling.

Steels that ordinarily are not classed as "self-hardening" might become hard on air cooling if the section is sufficiently small, while unusually large sections of some "self-hardening" steels may not become sufficiently hard on merely air cooling.

QUESTION NO. 96. Can the structure of a piece of steel be determined by the microscope applied to the fracture of a cross section, without polishing and etching the fracture, say of a stamping die 6 x 2 x 3½ inches, that has been hardened and broken in half, that is, are the different structural phenomena known as austenite, martensite, sorbite, ferrite, etc., so determinable?

QUESTION NO. 97. What degree of heat is required to change austenite to martensite, troosite, etc?

QUESTION NO. 98. What heat treatment will give a pure martensite structure throughout the hardened area of a piece of steel 6 x 2 x 3½ inches?

News of the Chapters

SCHEDULED REGULAR MEETING NIGHTS

FOR the convenience of visiting members, those chapters having regular meeting nights are listed below. It is desired that all secretaries whose chapters are not included in the list communicate with the National office in order that the list may be as complete as possible.

Cleveland—Fourth Friday, Cleveland Engineering Society rooms, Hotel Winton; meeting at 8 p. m.

New Haven—Third Friday.

New York—Third Wednesday, assembly room, Merchants Association of New York, ninth floor, Woolworth building.

Tri City—Third Thursday.

CINCINNATI CHAPTER

THE Cincinnati chapter of the American Society for Steel Treating held its first regular meeting of the season on Thursday October 11 at 8 p. m. in the Ohio Mechanics Institute. The paper of the evening entitled "Pyrometers" was presented by John H. Ames, works manager, Merrill Chemical company. This was the second installment on the subject that Mr. Ames has given and its presentation brought forth many interesting and instructive points.

BOSTON CHAPTER

The first monthly meeting of the Boston chapter was held Thursday evening, Oct. 25, 1923 at 6:30 p.m. at the Unity House, Park Square, Boston, at which time a cafeteria supper was served. Following the supper the usual sing of popular songs took place. The executive committee have found that the practice of having a "sing" at each meeting helps materially in promoting good-fellowship and in getting the members better acquainted with each other. One of the principal aims of the Boston chapter this year in addition to taking definite steps to increase our membership is to see that all members become acquainted on a personal and friendly basis.

Following the supper and social time a report of the chapter's delegate at the Pittsburgh convention was read and a unanimous vote was passed by the Boston chapter instructing the secretary to send a written invitation to the National Society to hold the convention in Boston

next year. Next a report was read by the chairman of the Program committee outlining the plans as arranged for the coming year and our chief interest was the meeting planned for November which proposes a trip in the afternoon to the Watertown Arsenal with supper and speeches by members of the arsenal personnel.

Following this business of the meeting a very interesting and instructive talk was delivered by Major A. E. Bellis of the Bellis Heat Treating Co., New Haven, Conn., and chairman of the Hardness Testing Committee of the National Research council on the subject of "Hardness Testing." Major Bellis took a few moments from his talk to assure the Boston chapter of co-operation from the New Haven chapter toward having the convention in Boston next year. Major Bellis then outlined the work of the Hardness Testing committee of the National Research council explaining the committee's purpose and aim and quoting directly from Dr. Hollnagel's paper printed in TRANSACTIONS last year and illustrating the necessity of arriving at some definite decision as to what hardness actually meant and how it should be tested. Major Bellis touched in a descriptive way, on all the various means and methods of hardness testing available and since he had brought with him one of the new Herbert hardness testers, a demonstration of this instrument was given and the talk swung directly into a very interesting discussion, principally concerning this new tester and Mr. DeForrest's method of magnetic hardness testing. Major Bellis's talk, was very interesting and instructive but what was even more satisfactory was the very general and complete discussion which followed and from which all obtained considerable information.

CLEVELAND CHAPTER

The first meeting of the season of the Cleveland chapter of the American Society for Steel Treating was held on Friday, October 26 in the rooms of the Cleveland Engineering society, Hotel Winton, at 8 p. m. This meeting was held for the purpose of renewing acquainatnce rather than for technical purposes. Those in attendance were entertained by orchestra and vocal selections. Dinner was served previous to the meeting at 7 p. m., at the Hamilton restaurant.

DETROIT CHAPTER

The Detroit chapter of the American Society for Steel Treating held its regular monthly meeting on Monday, Oct. 29 in the General Motors building, Wing E, fifteenth floor at 8:00 p.m. The speaker of the evening was Professor H. M. Boylston, Case School of Applied Science, Cleveland who spoke on "Metallurgy—Past, Present and Future." There were a large number of slides shown to illustrate this lecture

and inasmuch as Professor Boylston is a recognized authority on the microstructure of metals, he had a message for both the practical and theoretical man. A very interesting and instructive discussion took place following this presentation. W. H. Eisenman, national secretary of the society was present at this meeting and gave a short address on matters of interest to the members of the society. Dinner was served previous to the meeting at 6:30 p.m. in the private dining room on the fourteenth floor of the General Motors building.

HARTFORD CHAPTER

The Hartford chapter of the American Society for Steel Treating held a regular monthly meeting on September 11. The speaker of the evening was H. M. Candee, Bristol company, Waterbury, Conn., who gave an exceedingly interesting paper on "Modern Automatic Heat Control on Industrial Furnaces." This paper was well illustrated with diagrams and its presentation was followed by a lively discussion.

LEHIGH VALLEY CHAPTER

The Lehigh Valley chapter of the American Society for Steel Treating held a joint meeting with the Engineers' Club on Friday evening, October 19 at 8 p. m., in the physical laboratory of the Lehigh University, Bethlehem, Pa. The speaker for this meeting was Bradley Stoughton, Ph. D., B. S., professor of metallurgy, Lehigh University, who chose for his subject "Heat Treatment of Cast Iron." This is a subject which has been under investigation for many years and Dr. Stoughton told of a new process which has been recently developed and which has proved to be very satisfactory. This meeting was very well attended and an interesting evening was spent by all.

MILWAUKEE CHAPTER

The Milwaukee chapter of the American Society for Steel Treating held a meeting on September 7th at which time the affairs of the chapter for the coming year were outlined. At this meeting the following new officers were elected: H. B. Knowlton, chairman; L. L. Tatum, vice chairman and H. J. Stein, secretary-treasurer. The board of directors of the chapter are A. W. Lorenz, H. G. Lloyd, R. A. Thornberry and Walter Guyer.

The chapter held a second meeting on September 25 at the Blatz hotel, dinner having been served previous to the meeting. The speaker of the evening was H. E. Scarbrough, industrial heating engineer, General Electric Company, Chicago, who chose for his subject "Industrial

Electric Heating." This paper was presented in a very capable manner and gave a birdseye view of existing applications of electrical heating including low and high temperature production. Lantern slides were shown of modern installations of low and high temperature equipment. A very interesting and instructive discussion followed.

The chapter held a regular meeting on Monday, October 22 at 8 p. m. in the Blatz hotel. Edwin T. Jackman, Firth-Sterling Steel Company, Chicago, was speaker of the evening, gave a very capable presentation choosing for his subject "Stainless Iron and Steel." A very interesting discussion followed the presentation of this paper. Dinner was served at 6 p. m. preceding the meeting.

NEW HAVEN CHAPTER

The New Haven chapter of the American Society for Steel Treating held their first meeting of the season on Friday, September 21 at the New Haven Yacht club, Morris Cove. At this meeting Major Hill, chairman of the chapter, presented W. G. Aurand, secretary of the chapter with a twenty gauge Marlin pump gun in honor of winning the membership contest conducted by the chapter during the past year. The speaker of the evening, W. J. Kaup, mechanical engineer, gave a very interesting talk entitled "Our Job." The following questions were answered by members: "How long should a tool be left in the quench?" was answered by James Black; "Should high-speed steel be used for drawing dies?" by J. F. Brooks; and H. C. Goodwill gave an answer to "How far would you go above the critical point in hardening with the Hump Furnace?" It has been reported that this meeting will long be remembered by those present. Dinner was served at 6:30 p. m. preceding the meeting.

The chapter held their second regular monthly meeting on October 19 at 8 p. m. in the auditorium of the Chase Metal Works, Waterbury, Conn. The topic for this meeting was entitled "Tool Room Troubles" presented by A. H. Kingsbury, Crucible Steel Company of America, Atha Works, Harrison, N. J. Inasmuch as this paper has been published in TRANSACTIONS all members were familiar with it and a very enthusiastic discussion ensued, the participants bringing up many interesting and instructive points. Dinner was served preceding the meeting at 6 p. m. at the Hotel Elton at which time the Waterbury members entertained those in attendance with vocational selections by Miss Gladys Hedberg and Mr. George Heywood. A very enjoyable time was spent by all.

NEW YORK CHAPTER

The New York chapter of the American Society for Steel Treating held a meeting on Wednesday, Oct. 17 at 8:15 p.m. in the assembly room

of the Merchants Association of New York. The program of the evening consisted of motion pictures being shown entitled "The Jewel of Industry." The film covered the following topics: Creation of Electrical Power at Niagara Falls; Manufacture of Carborundum and Aloxite; Making of Grinding Wheels, Abrasive Papers, Abrasive Cloth, and Sharpening Stones. Francis D. Bowman, Carborundum Company, Niagara Falls, gave an explanatory lecture during the presentation of the pictures. C. E. Hawke, of the Carborundum Company, gave a practical and scientific talk entitled "Refractories for Heat Treating Furnaces."

Dinner was served at the Post Keller restaurant at 6:30 p.m.

The chapter is making preparations for the first annual New York chapter smoker to be held on Nov. 21 at the Cafe Boulevard. A good time is anticipated.

NORTHWEST CHAPTER

The Northwest chapter of the American Society for Steel Treating held a regular meeting on Tuesday, October 23 at 7:45 p. m. in the Manufacturers' club. A paper entitled "Stainless Steel" was presented by Edwin T. Jackman, Firth-Sterling Steel Company, Chicago. Mr. Jackman, a recognized authority on this subject, gave a very capable presentation which was followed by much interesting discussion. Chairman H. K. Briggs spoke of some of the papers of outstanding interest presented at the convention as well as some of the important exhibits of heat treating equipment and materials displayed at the exhibition in connection with the convention. This meeting was well attended and proved highly successful.

PHILADELPHIA CHAPTER

The Philadelphia chapter of the American Society for Steel Treating held a meeting on Friday evening, Sept. 28 at which time the chapter resolved to offer one or more free scholarships in the course in metallography given this year at Temple University and a committee was appointed to formulate and carry to a conclusion plans for the selection and appointment of men to these scholarships. The committee has accordingly formulated the following rules to govern this work: (1). With the object of improving the art of treating steel by the better training of men engaged in this art, the Philadelphia chapter offers for the term 1923-24 at least three free scholarships in the course in metallography given under its direction at Temple University. (2). These scholarships are open to any man eligible to (active or associate) membership in the Philadelphia chapter. (3). It is expected that there will be more applicants than scholarships to be awarded and the committee will accept from the applicants the ones who in its opinion

are best fitted to derive the greatest benefit from the course. (4). Men receiving these scholarships will be required to attend the course regularly and to maintain a satisfactory average of scholarship. The director of the course will report monthly to the committee on each man holding a scholarship. Failure to come up to the scholastic requirements of the course will be considered as sufficient reason to withdraw such scholarship at any time. When through such withdrawal or from other reasons a scholarship is vacant, it will be immediately filled by the committee from the list of previous applicants.

It is believed that this will work out very satisfactorily.

RHODE ISLAND CHAPTER

The October meeting of the Rhode Island chapter of the American Society for Steel Treating was held on Tuesday, October 2 at 8 p. m. in the rooms of the Providence Engineering Society, 44 Washington street. This meeting was addressed by Joseph A. Doyle, vice president W. S. Rockwell Company, New York City, who chose for his subject "Methods of Heating and Cooling." Mr. Doyle who is an authority on the heat treatment of steel, spoke about the first principles in the heating and cooling of steel from a practical standpoint.

ROCHESTER CHAPTER

The Rochester chapter of the American Society for Steel Treating held a meeting on Wednesday evening, Oct. 31 in the rooms of the Rochester Engineering society. The speaker for this meeting was J. B. Deisher, assistant superintendent, T. H. Symington Company, Lincoln Park Works, Rochester, who chose for his subject "The Heat Treatment of Málleable Iron". Mr. Deisher gave a very capable presentation describing the process of the heat treatment of malleable iron, the problems dealt with and its adaptability to industry. This paper was illustrated with lantern slides and specimens were displayed. A very interesting discussion followed the presentation of the paper.

SCHENECTADY CHAPTER

The Schenectady chapter of the American Society for Steel Treating held a regular monthly meeting on Friday, Oct. 26 at 8:00 p.m. in the Civil Engineering building, Union College. The chapter was honored by having Dr. Burgess the new president of the society as well as new director of the Bureau of Standards make his first chapter visit at their meeting. Dr. Burgess spoke on recent metallurgical work at the Bureau. He also discussed the effect of high temperatures on metals and efficiency tests of high-speed steel. William H. Eisenman, national secretary of the society was also present and gave as usual, an enthusiastic talk on the affairs of the A. S. S. T.

On Saturday, Dr. Burgess was the guest of the General Electric Research Laboratory. He spoke on the work of the Bureau in general, and particularly its bearing on the electrical industries.

SPRINGFIELD CHAPTER

The Springfield chapter of the American Society for Steel Treating held a meeting on Tuesday, October 23 at 8 p. m. at the Froiland Chain & Mfg. Company, 139 North Main street. The speaker of the evening was K. A. Juthe of the American Electric Furnace Corporation, Boston, who spoke on "Electric Furnaces." Mr. Juthe, who is a manufacturer is well qualified on this subject and after his very able presentation he gave a demonstration of one of the finest installations of electric furnaces in this section of the country.

SYRACUSE CHAPTER

The Syracuse chapter of the American Society for Steel Treating held their first fall meeting on September 28 at the Yates Hotel. The program of the evening consisted of a film being shown through the courtesy of the Carborundum Company of Niagara Falls, covering the following topics: Complete story of the creation of Niagara Falls Power; Beautiful scenic views in and about Niagara; details study of the manufacture of the abrasives, "Carborundum and Aloxite;" a comprehensive insight to the uses of modern abrasives in plants of all kinds and character ranging from the grinding of steel castings. Francis D. Bowman, advertising manager of the Carborundum Company delivered a short explanatory lecture during the exhibition of the film and he was accompanied by an expert who answered questions regarding grinding operations. Dinner was served previous to the meeting at 6:30 at the Yates Hotel.

TRI CITY CHAPTER

On Oct. 17, the Tri City chapter of the American Society for Steel Treating opened a night school course at the Rock Island Manual Arts high school, and will continue on each Wednesday evening for a period of twenty weeks. A series of lectures on "Steel and Its Treatment" will be given during the course, which outline is as follows: (1). Manufacture of Steel. (2), Rolling of Steel—From Ingot to Finished Steel. (3), Composition and Uses of Steel. (4), Furnaces and Fuel. (5), Pyrometry. (6), Review of Lectures 1 to 5 inclusive. (7), Alloy Steels. (8), Annealing and Normalizing. (9), Hardening. (10), Tempering. (11), Testing of Steel, Chemical and Physical. (12), Review of Lectures 7 to 11 inclusive. (13), Carburizing. (14), Forging. (15),

Cast Iron and Malleable Cast Iron. (16), Steel Castings. (17), Tool Steels. (18), Microstructure of the Metals. (19), Microstructure of the Metals. (20), Review of Lectures 13 to 19 inclusive.

The school is under the direct supervision of C. H. Burgston who is chairman of the educational extension committee of the chapter.

The first lecture of the series entitled "The Manufacture of Steel" was presented by A. H. Putnam of Davenport, Iowa, on the opening night at which time there were about one hundred in attendance. The chapter is very much satisfied with the success of the undertaking as the response has been very gratifying.

Editors Note:—This is a most commendable undertaking and we are looking forward to great results from this activity.

The chapter held its second regular meeting on Thursday, Oct. 25 at the Davenport chamber of commerce. Professor H. F. Moore, University of Illinois, Urbana, Ill., addressed the chapter at this meeting on the subject "The Fatigue of Metals." Professor Moore has been in charge of the investigation of the subject which is being carried on by the University of Illinois, the National Research council, the General Electric Company and several other of the larger industries. A very lively and interesting discussion followed the presentation of Professor Moore's paper.

WASHINGTON CHAPTER

The first meeting of the fall season of the Washington chapter of the American Society for Steel Treating was held on Friday, September 28 at 8 p. m. in the auditorium of the New Interior Department building. This meeting consisted of an informal assembly to give members and guests an opportunity to renew acquaintances. A general discussion of several metallurgical topics had been arranged and illustrated presentations were given by the following members with their respective subjects: "Protective Coatings for Selective Case-Hardening," by J. S. Vanick; "Heat Treatment of High-Speed Steel" by H. J. French and "Continuous Heat Treatment" by W. F. Graham.

The meeting was well attended and an enjoyable evening was spent by all.

The second monthly meeting of the chapter was held on Friday, October 19 at 8 p. m. in the auditorium of the New Interior Department building. The speaker for the evening was H. A. Schwartz, director of research, National Malleable Castings Company, Cleveland, who chose for his subject "Malleable Iron." The speaker, who is nationally recognized as an authority on this subject described the manufacture, properties and applications of malleable iron. His presentation was based on wide practical experience and years of scientific research with one of the large producers.

Abstracts of Technical Articles

Brief Reviews of Publications of Interest to Metallurgists and Steel Treaters

STRUCTURE OF CHROMIUM-NICKEL STEEL. By H. B. Pulsifer and O. V. Greene in *Chemical and Metallurgical Engineering*, No. 28, 1923, page 354.

The authors of this article show how micrographs do not reveal any change in structure in quenched chromium-nickel steel after various draws, though there are large differences in the physical properties. Precautions are given for etching and photographing.

INFLUENCE OF TEMPERATURE, TIME AND RATE OF COOLING ON PHYSICAL PROPERTIES OF CARBON STEEL. By H. M. Howe, F. B. Foley and Jos. Winlock, in *Transactions*, American Institute of Mining and Metallurgical Engineers, No. 1226-S, (1923).

In this article steels of 0.34, 0.52 and 0.75 per cent carbon were subjected to various temperatures above Ac_3, held for 10, 60 and 120 minutes and cooled at various rates; their tensile properties, hardness and resistance to impact were then compared. 0.52 per cent carbon steel was quenched in water from different temperatures above Ac_3 and drawn at a number of temperatures below Ac_1. The same steel was subjected to repeated heatings and the physical properties were determined. The specimens were treated in 7/8-inch round sections.

MAGNETIC CHANGE A_2 IN SILICON AND CHROMIUM STEELS. By Howard Scott in *Chemical and Metallurgical Engineering*, No. 28, 1923, page 212.

This article states that it is impossible to rely upon the loss of magnetism to indicate proper hardening temperatures for these steels, since the carbon change point is at a higher temperature than the magnetic change point.

HEAT TREATMENT OF STEEL CASTINGS. By H. C. Ihsen in *Blast Furnace and Steel Plant* No. 11, 1923, page 95.

There is considered in this article the characteristics of steel castings in the raw and in the thermally treated condition. A consideration of the correct treatment with relation to size and composition of casting is given.

FORGING, ANNEALING, HARDENING AND TEMPERING TOOL STEEL. By E. J. O'Leary, heat-treating expert, Midvale Steel Co., San Francisco, in *Western Machinery World*, July, 1923, page 227.

This paper explains in detail how these four operations can be accomplished, and tells the kind of steel that should be selected for each use.

Reviews of Recent Patents

1,452,810. Apparatus for Testing the Hardness of Metals and other Materials. Harold Moore and Richard Mather, Woolwick, England.

The above invention relates to an apparatus for testing the hardness of materials comprising a support for the specimen to be tested, a hardened steel ball arranged above said support, a stirrup carrying said hardened steel ball and adapted to carry a known weight, and means for lowering said stirrup so that said ball is pressed into contact with said specimen under said known load.

1,452,856. Heating Furnace. Willibald Trinks, Pittsburgh, Pa., assignor to Tate-Jones & Co., Inc., Leetsdale, Pa., a corporation of Pennsylvania.

This patent refers to a heating furnace with a annular, horizontal rotating hearth table, independent vertically adjustable supports for said table, an enclosed inspection pit below said table, sand seals between the heating chamber and the inspection pit, a plurality of regulable air admission openings at the outer circumference of the inspection pit, and a plurality of ducts leading from said pit to a central stack.

1,452,936. Method of and Apparatus for Welding. Frank J. Schuman, Cleveland Heights, Ohio, assignor to the Allan Manufacturing and Welding Corporation, Buffalo, a corporation of New York.

This relates to a method of filling recesses in iron articles, the steps which consist in establishing a closed electrical circuit through a nickel pencil and the wall of such recess until a drop of the nickel has melted and deposited, and then moving such pencil to a new point on such wall and repeating such operation.

1,453,097. Multiple-Unit Induction Furnace. Charles B. Foley, Bristol, Conn., assignor to Charles B. Foley, Inc., New York City, a corporation of New York.

The above patent refers to an electric furnace comprising a receptacle of refractory material, having interior walls forming channels, and independent current-inducing means linked with said channels said current inducing means being so connected as to produce secondary electromotive forces of the same direction.

ADDRESSES OF NEW MEMBERS OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

NEW MEMBERS

ALKEMA, RICHARD H. (M-4), 226 Adelaide Street, Indianapolis, Ind.
ARDOUIN, L. A. (A-2), United States Steel Products Co., Los Angeles, Cal.
ARNOLD, SAMUEL 3RD. (M-10), c/o Tate-Jones & Co., Inc, Leetsdale, Pa.
ASHCRAFT, THOMAS (M-9), 216 Willow Street, W. Roxbury, Boston, Mass.
AYLING, H. J. (A-6), 70 Crown Street, New Haven, Conn.
BAILEY, FRANK E. (M-9), 376 McKee Place, Pittsburgh.
BARDES, DWIGHT L. (A-10), 937 Oliver Bldg., Pittsburgh.
BARNES, H. L. (S-8), Hartford City Gas Light Co., Hartford, Conn.
BATH, JOHN (S-10), 8 Grafton Street, Worcester, Mass.
BENSON, EARLE G. (Jr-10), 1814 Fifteenth Ave., Moline, Ill.
BENTER, WALTER P. (M-9), Box 644, Midland, Pa.
BERGEN, H. S. (M-10), c/o Toledo Scale Co., Toledo, Ohio.
BISCHOFF, W. G. (J-10) 239 West Tenth Ave., Columbus, Ohio.
BLAIR, W. J. (M-10), 104 Montview Ave., Toronto, Ontario, Canada.
BOARD, RICHARD C. (M-10), c/o Crucible Steel Company, of America, Pittsburgh.
BODKIN, J. S. (M-10), c/o Auto Strop Safety Razor Co., 656 First Ave., New York City.
BRIDEN, FRANK H. (M-10), Nicholson File Co., Port Hope, Ontario, Canada.
BRINCKERHOFF, JOHN H. (M-10), Ingersoll-Rand Co., Phillipsburg, N. J.
BRUYETTE, H. L. (M-7), New Departure Mfg. Co., Bristol, Conn.
BUTKISS, MICHAEL (M-3), 2724 Fourth Street, Detroit.
CASTINE, CLARENCE (M-10), Harley Davison Motor Co., Milwaukee, Wis.
CHANDLER, F. C. JR. (M-10), Chandler Motor Car Co., Cleveland.
CHATILLON, R. R. (M-11), Foster Bros. & Chatillon Co., Fulton, N. Y.
CLEMENTS, B. (M-9), 162 Barton St., Buffalo, N. Y.
COOK, R. G. (M-11), Bethlehem Steel Company, Bethlehem, Pa.
CORNELL, EDGAR, JR. (M-3), 2200 Perrysville Ave., N. S. Pittsburgh.
CURRY, WILLIAM J. (M-10), Tioga Steel & Iron Co., Philadelphia.
DALE, ANSEL (M-11), 5136 E. Walnut Street, Indianapolis, Ind.
DAVIS, HUGH F. (M-10), 20 Carrick Ave., Hamilton, Ontario, Canada.
DEMMLER, A. W. (M-10), 217 Stratford Avenue, Pittsburgh.
DONNELLY, W. W. (M-10), Federal Supply Company, Fort Worth, Texas.
DOWN, WILLIAM R. (M-10), Locust Street, Fleetwood, Pa.
DRAVO, M. S. (S-9), Crucible Steel Company of America, Pittsburgh.
DRISCOLL, J. J. (M-9), 104 Magnolia Street, Syracuse, N. Y.
EASTMAN KODAK COMPANY (S-10), Library, Kodak Park Wks., Rochester, N. Y.
ELLICOTT, C. R. (M-11), Bethlehem Steel Company, Bethlehem, Pa.

FITCH, GRANT (M-9), 202 North Lang Avenue, Pittsburgh.
FLOHR, RALPH C. (M-10), American Tool Works Company, Cincinnati, Ohio.
FORD, ALFRED (M-10), Chicago Nipple Manufacturing Company, Chicago.
GATHMAN, EMIL (S-9), Gathman Engineering Company, Baltimore, Md.
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GRAYSON, SYDNEY A. (M-9), Jessop Steel Company, Washington, Pa.
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GROBSTEIN, ALBERT (M-10), 1032 Chislett Street, Pittsburgh.
GROH, PAUL (M-9), 5700 Roosevelt Road, Chicago.
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HOLLAND, GEORGE F. (M-10), c/o Butterfield & Company, Derby Line, Vt.
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JOHNSON, EDWARD D. (M-11), 60 Twenty-seventh Street, Milwaukee, Wis.
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LESTER, H. H., Dr. (M-8), Watertown Arsenal, Watertown, Mass.
LETZ, CARRY A. (M-10), Gurney Ball Bearing Company, Jamestown, N. Y.
LOTT, A. L. (M-10), Gananoque, Ontario, Canada.
LUCAS, FRANCIS F. (M-10), 463 West Street, New York City.
MACGREGOR, A. R. (M-9), Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
MCCONWAY & TORLEY COMPANY, (S-10), 48th Street and A. V. Ry., Pittsburgh.
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MALEY, STANLEY (M-9), 1835 S. 56th Ct., Cicero, Ill.
MALONE, E. L. (A-9), Calorizing Co., 50 Church Street, New York, N. Y.

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MELLEN, WILLIAM F. (M-10), Garwood Brass & Copper Company, Garwood, N. J.
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MULL, J. W., JR. (A-11), 717 Fletcher Trust Bldg., Indianapolis, Ind.
MURFEY, A. A. (S-9), Cleveland File Company, Cleveland, Ohio.
NAUSS, GEORGE M. (M-10), Crown Cork & Seal Company, Baltimore, Md.
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OBERBERGER, ALBERT FRED (M-10), 410 Washington St., Milwaukee, Wis.
OLDFIELD, H. S. (M-10), 28 Linden Ave., Lansdowne, Pa.
PAFENBACH, A. ROY (M-10), 307 Penn Avenue, Wilkinsburg, Pa.
PANNIER, OSCAR M. (M-10), 207 Sandusky Street, Pittsburgh.
PARADISE, L. A. (M-10), 927 Twenty-fifth St., Moline, Ill.
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REANEY, J. F. (M-10), Evangeline Iron Works, Ltd., Vinton, La.
RICHARDS, DAVID J. (A-9), 907 Bessemer Bldg., Pittsburgh.
RITZER, WILLIAM G. (M-4), 241 Fulton Street, Jamestown, N. Y.
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ROY, JAMES E. (M-10), 37 S. Seventh Street, Darby, Pa.
RUBY, LEONARD E. (M-10), Box 19, Newport News, Va.
SCHMELZ, CHARLES F. (M-10), Curtis & Curtis Company, Bridgeport, Conn
SCHULZ, H. B. (M-9), Illinois Steel Company, S. Chicago, Ill.
SHEAFF, HOWARD (M-11), 1440 Broadway, New York City.
SIMMONS, O. G. (M-10), National Tool Company, Cleveland.
SIMMONS, RAYMOND S. (M-10), Monesson, Pa.
SMITH, ERNEST L. (A-10), 2-220 General Motors Bldg., Detroit.
SMITH, W. P. (M-4), 244 Brown Avenue, Turtle Creek, Pa.
SPEICKER, F., JR. (M-10), 207 Sandusky St., Pittsburgh.
STEGEMAN, HENRY J. (M-10), The Locke Steel Chain Co., Bridgeport, Conn.
STEVENSON, R. R. (M-10), 216 Valley Street, McDonald, Pa.
STRITE, HOWARD W. (M-10), 37 Lombardy Street, Lancaster, Pa.
STURRACK, J., JR. (M-10), Ingersoll-Rand Co., Athens, Pa.
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TISDALE, N. F. (A-10), 1274 Ontario Street, Cleveland.
TOWNSEND, MATHEW M. (M-10), 260 Gross Street, Pittsburgh.
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UNION HARDWARE COMPANY (S-10), Torrington, Conn.
WARD, A. C. (M-9), 43 Somerset Street, Springfield, Mass.

WATERHOUSE, PROF. GEORGE B. (M-10), Massachusetts Institute of Technology, Cambridge, Mass.
WEAVER, ALFRED J. (M-9), 85 Grandview Terrace, Hartford, Conn.
WELCH, HUGH L. (A-10), 1504 Broadway, Detroit.
WEYDELL, AXEL (M-9), 419 E. North Street, Indianapolis, Ind.
WHALAN, JOSEPH P. (M-10), American La France Fire Engine Co., Bloomfield, N. J.
WRIGHT, CHARLES L. (M-4), 714 Second Street, Watervliet, N. Y.
YOUNG, R. S. (M-10), 107 Buena Vista Avenue, Yonkers, N. Y.
ZETTENWALL, G. A. (M-7), 35 Olive Street, New Britain, Conn.

CHANGES OF ADDRESS

BADGER, A. C. from 49 Parker Street, Watertown, Mass., to Youngstown Sheet & Tube Company, Youngstown, Ohio.
BOHNER, C. M. from 143 Hall Street, Akron, Ohio, to 524 West 123rd Street, New York City.
CHAMBERS, A. A. from 225½ Thirty-second Street, Milwaukee, Wis. to 583 Willis Avenue, Youngstown, Ohio.
ECKENRODE, C. A. from 351 Darrah Street to 3382 Webster Avenue, Pittsburgh.
FAULKNER, B. from 69 Donlands Avenue to 606 Greenwood Avenue, Toronto, Ont. Canada.
GOLDCAMP, C. F. from 337 Atwood Street to 65 Parkview Avenue, Pittsburgh.
GREEMAN, O. W. from 1933 College Avenue to 1441 East 11th Street, Indianapolis, Ind.
HARRITY, E. E. from 107 Camp Avenue to 626 Fourth Street, Braddock, Pa.
JAYME, W. A. from 1120 Piedmont Avenue, Canton, Ohio to Crucible Steel Co., of America, Thirtieth and Smallman Streets, Pittsburgh.
KUTAR, P. from 204 Robinson Street to 329 Meyran Avenue, Pittsburgh.
NICKLE, H. D. from 532 Beacon Street to 432 Marlboro Street, Boston.
OLSEN, G. JR. from 1814 Farnum Street, Davenport, Iowa, to 1317 Twenty-Fifth Avenue, Moline, Ill.
SISCO, F. T. from P. O. Box 3, Waukegan, Ill. to Box 214, Dayton, Ohio.
SPENCER, M. P. from 608 West Adams Street, Chicago to Halcomb Steel Co., Syracuse, N. Y.

MAIL RETURNED

GANSER, J. N., Acme Machine Company, Mishawaka, Ind.